3 Vol

A TREATISE

ON

REFRIGERATING

AND

ICE-MAKING MACHINERY

PREPARED FOR STUDENTS OF

THE INTERNATIONAL CORRESPONDENCE SCHOOLS

SCRANTON, PA.

Volume IV

TABLES AND FORMULAS

First Edition

SCRANTON

THE COLLIERY ENGINEER CO.

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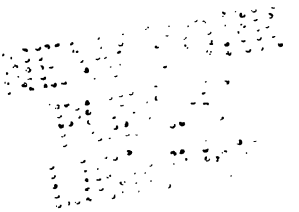
TABLES AND FORMULAS.

This volume contains all the principal Tables and Formulas which are likely to be used in practice. They have been collected and placed in this volume to make them convenient for ready reference, so that the student will not be obliged to hunt them out in the preceding volumes. The number after each formula is the same as the number following the same formula in the text.



TABLE

OF

COMMON LOGARITHMS

OF NUMBERS

From 1 to 10,000.

N	Log.	N.	Log.	N.	Log.	N.	Log.	N.	Log.
0	— ∞	**20**	30 103	**40**	60 206	**60**	77 815	**80**	90 309
1	00 000	21	32 222	41	61 278	61	78 533	81	90 849
2	30 103	22	34 242	42	62 325	62	79 239	82	91 381
3	47 712	23	36 173	43	63 347	63	79 934	83	91 908
4	60 206	24	38 021	44	64 345	64	80 618	84	92 428
5	69 897	25	39 794	45	65 321	65	81 291	85	92 942
6	77 815	26	41 497	46	66 276	66	81 954	86	93 450
7	84 510	27	43 136	47	67 210	67	82 607	87	93 952
8	90 309	28	44 716	48	68 124	68	83 251	88	94 448
9	95 424	29	46 240	49	69 020	69	83 885	89	94 939
10	00 000	**30**	47 712	**50**	69 897	**70**	84 510	**90**	95 424
11	04 139	31	49 136	51	70 757	71	85 126	91	95 904
12	07 918	32	50 515	52	71 600	72	85 733	92	96 379
13	11 394	33	51 851	53	72 428	73	86 332	93	96 848
14	14 613	34	53 148	54	73 239	74	86 923	94	97 313
15	17 609	35	54 407	55	74 036	75	87 506	95	97 772
16	20 412	36	55 630	56	74 819	76	88 081	96	98 227
17	23 045	37	56 820	57	75 587	77	88 649	97	98 677
18	25 527	38	57 978	58	76 343	78	89 209	98	99 123
19	27 875	39	59 106	59	77 085	79	89 763	99	99 564
20	30 103	**40**	60 206	**60**	77 815	**80**	90 309	**100**	00 000

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
100	00 000	043	087	130	173	217	260	303	346	389	
101	432	475	518	561	604	647	689	732	775	817	
102	860	903	945	988	*030	*072	*115	*157	*199	*242	
103	01 284	326	368	410	452	494	536	578	620	662	44 43 42
104	703	745	787	828	870	912	953	995	*036	*078	1 4.4 4.3 4.2
105	02 119	160	202	243	284	325	366	407	449	490	2 8.8 8.6 8.4
106	531	572	612	653	694	735	776	816	857	898	3 13.2 12.9 12.6
107	938	979	*019	*060	*100	*141	*181	*222	*262	*302	4 17.6 17.2 16.8
108	03 342	383	423	463	503	543	583	623	663	703	5 22.0 21.5 21.0
109	743	782	822	862	902	941	981	*021	*060	*100	6 26.4 25.8 25.2
110	04 139	179	218	258	297	336	376	415	454	493	7 30.8 30.1 29.4
111	532	571	610	650	689	727	766	805	844	883	8 35.2 34.4 33.6
112	922	961	999	*038	*077	*115	*154	*192	*231	*269	9 39.6 38.7 37.8
113	05 308	346	385	423	461	500	538	576	614	652	41 40 39
114	690	729	767	805	843	881	918	956	994	*032	1 4.1 4.0 3.9
115	06 070	108	145	183	221	258	296	333	371	408	2 8.2 8.0 7.8
116	446	483	521	558	595	633	670	707	744	781	3 12.3 12.0 11.7
117	819	856	893	930	967	*004	*041	*078	*115	*151	4 16.4 16.0 15.6
118	07 188	225	262	298	335	372	408	445	482	518	5 20.5 20.0 19.5
119	555	591	628	664	700	737	773	809	846	882	6 24.6 24.0 23.4
120	918	954	990	*027	*063	*099	*135	*171	*207	*243	7 28.7 28.0 27.3
121	08 279	314	350	386	422	458	493	529	565	600	8 32.8 32.0 31.2
122	636	672	707	743	778	814	849	884	920	955	9 36.9 36.0 35.1
123	991	*026	*061	*096	*132	*167	*202	*237	*272	*307	38 37 36
124	09 342	377	412	447	482	517	552	587	621	656	1 3.8 3.7 3.6
125	691	726	760	795	830	864	899	934	968	*003	2 7.6 7.4 7.2
126	10 037	072	106	140	175	209	243	278	312	346	3 11.4 11.1 10.8
127	380	415	449	483	517	551	585	619	653	687	4 15.2 14.8 14.4
128	721	755	789	823	857	890	924	958	992	*025	5 19.0 18.5 18.0
129	11 059	093	126	160	193	227	261	294	327	361	6 22.8 22.2 21.6
130	394	428	461	494	528	561	594	628	661	694	7 26.6 25.9 25.2
131	727	760	793	826	860	893	926	959	992	*024	8 30.4 29.6 28.8
132	12 057	090	123	156	189	222	254	287	320	352	9 34.2 33.3 32.4
133	385	418	450	483	516	548	581	613	646	678	35 34 33
134	710	743	775	808	840	872	905	937	969	*001	1 3.5 3.4 3.3
135	13 033	066	098	130	162	194	226	258	290	322	2 7.0 6.8 6.6
136	354	386	418	450	481	513	545	577	609	640	3 10.5 10.2 9.9
137	672	704	735	767	799	830	862	893	925	956	4 14.0 13.6 13.2
138	988	*019	*051	*082	*114	*145	*176	*208	*239	*270	5 17.5 17.0 16.5
139	14 301	333	364	395	426	457	489	520	551	582	6 21.0 20.4 19.8
140	613	644	675	706	737	768	799	829	860	891	7 24.5 23.8 23.1
141	922	953	983	*014	*045	*076	*106	*137	*168	*198	8 28.0 27.2 26.4
142	15 229	259	290	320	351	381	412	442	473	503	9 31.5 30.6 29.7
143	534	564	594	625	655	685	715	746	776	806	32 31 30
144	836	866	897	927	957	987	*017	*047	*077	*107	1 3.2 3.1 3.0
145	16 137	167	197	227	256	286	316	346	376	406	2 6.4 6.2 6.0
146	435	465	495	524	554	584	613	643	673	702	3 9.6 9.3 9.0
147	732	761	791	820	850	879	909	938	967	997	4 12.8 12.4 12.0
148	17 026	056	085	114	143	173	202	231	260	289	5 16.0 15.5 15.0
149	319	348	377	406	435	464	493	522	551	580	6 19.2 18.6 18.0
50	609	638	667	696	725	754	782	811	840	869	7 22.4 21.7 21.0
											8 25.6 24.8 24.0
											9 28.8 27.9 27.0
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150	17 609	638	667	696	725	754	782	811	840	869	
151	898	926	955	984	*013	*041	*070	*099	*127	*156	
152	18 184	213	241	270	298	327	355	384	412	441	**29** **28**
153	469	498	526	554	583	611	639	667	696	724	1 2.9 2.8
154	752	780	808	837	865	893	921	949	977	*005	2 5.8 5.6
155	19 033	061	089	117	145	173	201	229	257	285	3 8.7 8.4
156	312	340	368	396	424	451	479	507	535	562	4 11.6 11.2
157	590	618	645	673	700	728	756	783	811	838	5 14.5 14.0
158	866	893	921	948	976	*003	*030	*058	*085	*112	6 17.4 16.8
159	20 140	167	194	222	249	276	303	330	358	385	7 20.3 19.6
160	412	439	466	493	520	548	575	602	629	656	8 23.2 22.4
161	683	710	737	763	790	817	844	871	898	925	9 26.1 25.2
162	952	978	*005	*032	*059	*085	*112	*139	*165	*192	
163	21 219	245	272	299	325	352	378	405	431	458	**27** **26**
164	484	511	537	564	590	617	643	669	696	722	1 2.7 2.6
165	748	775	801	827	854	880	906	932	958	985	2 5.4 5.2
166	22 011	037	063	089	115	141	167	194	220	246	3 8.1 7.8
167	272	298	324	350	376	401	427	453	479	505	4 10.8 10.4
168	531	557	583	608	634	660	686	712	737	763	5 13.5 13.0
169	789	814	840	866	891	917	943	968	994	*019	6 16.2 15.6
170	23 045	070	096	121	147	172	198	223	249	274	7 18.9 18.2
171	300	325	350	376	401	426	452	477	502	528	8 21.6 20.8
172	553	578	603	629	654	679	704	729	754	779	9 24.3 23.4
173	805	830	855	880	905	930	955	980	*005	*030	
174	24 055	080	105	130	155	180	204	229	254	279	**25**
175	304	329	353	378	403	428	452	477	502	527	1 2.5
176	551	576	601	625	650	674	699	724	748	773	2 5.0
177	797	822	846	871	895	920	944	969	993	*018	3 7.5
178	25 042	066	091	115	139	164	188	212	237	261	4 10.0
179	285	310	334	358	382	406	431	455	479	503	5 12.5
180	527	551	575	600	624	648	672	696	720	744	6 15.0
181	768	792	816	840	864	888	912	935	959	983	7 17.5
182	26 007	031	055	079	102	126	150	174	198	221	8 20.0
183	245	269	293	316	340	364	387	411	435	458	9 22.5
184	482	505	529	553	576	600	623	647	670	694	
185	717	741	764	788	811	834	858	881	905	928	**24** **23**
186	951	975	998	*021	*045	*068	*091	*114	*138	*161	1 2.4 2.3
187	27 184	207	231	254	277	300	323	346	370	393	2 4.8 4.6
188	416	439	462	485	508	531	554	577	600	623	3 7.2 6.9
189	646	669	692	715	738	761	784	807	830	852	4 9.6 9.2
190	875	898	921	944	967	989	*012	*035	*058	*081	5 12.0 11.5
191	28 103	126	149	171	194	217	240	262	285	307	6 14.4 13.8
192	330	353	375	398	421	443	466	488	511	533	7 16.8 16.1
193	556	578	601	623	646	668	691	713	735	758	8 19.2 18.4
194	780	803	825	847	870	892	914	937	959	981	9 21.6 20.7
195	29 003	026	048	070	092	115	137	159	181	203	
196	226	248	270	292	314	336	358	380	403	425	**22** **21**
197	447	469	491	513	535	557	579	601	623	645	1 2.2 2.1
198	667	688	710	732	754	776	798	820	842	863	2 4.4 4.2
199	885	907	929	951	973	994	*016	*038	*060	*081	3 6.6 6.3
200	30 103	125	146	168	190	211	233	255	276	298	4 8.8 8.4
											5 11.0 10.5
											6 13.2 12.6
											7 15.4 14.7
											8 17.6 16.8
											9 19.8 18.9
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
200	30 103	125	146	168	190	211	233	255	276	298	
201	320	341	363	384	406	428	449	471	492	514	
202	535	557	578	600	621	643	664	685	707	728	
203	750	771	792	814	835	856	878	899	920	942	
204	963	984	*006	*027	*048	*069	*091	*112	*133	*154	
205	31 175	197	218	239	260	281	302	323	345	366	
206	387	408	429	450	471	492	513	534	555	576	
207	597	618	639	660	681	702	723	744	765	785	
208	806	827	848	869	890	911	931	952	973	994	
209	32 015	035	056	077	098	118	139	160	181	201	
210	222	243	263	284	305	325	346	366	387	408	
211	428	449	469	490	510	531	552	572	593	613	
212	634	654	675	695	715	736	756	777	797	818	
213	838	858	879	899	919	940	960	980	*001	*021	
214	33 041	062	082	102	122	143	163	183	203	224	
215	244	264	284	304	325	345	365	385	405	425	
216	445	465	486	506	526	546	566	586	606	626	
217	646	666	686	706	726	746	766	786	806	826	
218	846	866	885	905	925	945	965	985	*005	*025	
219	34 044	064	084	104	124	143	163	183	203	223	
220	242	262	282	301	321	341	361	380	400	420	
221	439	459	479	498	518	537	557	577	596	616	
222	635	655	674	694	713	733	753	772	792	811	
223	830	850	869	889	908	928	947	967	986	*005	
224	35 025	044	064	083	102	122	141	160	180	199	
225	218	238	257	276	295	315	334	353	372	392	
226	411	430	449	468	488	507	526	545	564	583	
227	603	622	641	660	679	698	717	736	755	774	
228	793	813	832	851	870	889	908	927	946	965	
229	984	*003	*021	*040	*059	*078	*097	*116	*135	*154	
230	36 173	192	211	229	248	267	286	305	324	342	
231	361	380	399	418	436	455	474	493	511	530	
232	549	568	586	605	624	642	661	680	698	717	
233	736	754	773	791	810	829	847	866	884	903	
234	922	940	959	977	996	*014	*033	*051	*070	*088	
235	37 107	125	144	162	181	199	218	236	254	273	
236	291	310	328	346	365	383	401	420	438	457	
237	475	493	511	530	548	566	585	603	621	639	
238	658	676	694	712	731	749	767	785	803	822	
239	840	858	876	894	912	931	949	967	985	*003	
240	38 021	039	057	075	093	112	130	148	166	184	
241	202	220	238	256	274	292	310	328	346	364	
242	382	399	417	435	453	471	489	507	525	543	
243	561	578	596	614	632	650	668	686	703	721	
244	739	757	775	792	810	828	846	863	881	899	
245	917	934	952	970	987	*005	*023	*041	*058	*076	
246	39 094	111	129	146	164	182	199	217	235	252	
247	270	287	305	322	340	358	375	393	410	428	
248	445	463	480	498	515	533	550	568	585	602	
249	620	637	655	672	690	707	724	742	759	777	
250	794	811	829	846	863	881	898	915	933	950	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

	22	21
1	2.2	2.1
2	4.4	4.2
3	6.6	6.3
4	8.8	8.4
5	11.0	10.5
6	13.2	12.6
7	15.4	14.7
8	17.6	16.8
9	19.8	18.9

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9	18.0

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5	9.5
6	11.4
7	13.3
8	15.2
9	17.1

	18
1	1.8
2	3.6
3	5.4
4	7.2
5	9.0
6	10.8
7	12.6
8	14.4
9	16.2

	17
1	1.7
2	3.4
3	5.1
4	6.8
5	8.5
6	10.2
7	11.9
8	13.6
9	15.3

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
250	39 794	811	829	846	863	881	898	915	933	950	
251	967	985	*002	*019	*037	*054	*071	*088	*106	*123	
252	40 140	157	175	192	209	226	243	261	278	295	**18**
253	312	329	346	364	381	398	415	432	449	466	1 | 1.8
254	483	500	518	535	552	569	586	603	620	637	2 | 3.6
255	654	671	688	705	722	739	756	773	790	807	3 | 5.4
256	824	841	858	875	892	909	926	943	960	976	4 | 7.2
257	993	*010	*027	*044	*061	*078	*095	*111	*128	*145	5 | 9.0
258	41 162	179	196	212	229	246	263	280	296	313	6 | 10.8
259	330	347	363	380	397	414	430	447	464	481	7 | 12.6
											8 | 14.4
260	497	514	531	547	564	581	597	614	631	647	9 | 16.2
261	664	681	697	714	731	747	764	780	797	814	
262	830	847	863	880	896	913	929	946	963	979	
263	996	*012	*029	*045	*062	*078	*095	*111	*127	*144	**17**
264	42 160	177	193	210	226	243	259	275	292	308	1 | 1.7
265	325	341	357	374	390	406	423	439	455	472	2 | 3.4
266	488	504	521	537	553	570	586	602	619	635	3 | 5.1
267	651	667	684	700	716	732	749	765	781	797	4 | 6.8
268	813	830	846	862	878	894	911	927	943	959	5 | 8.5
269	975	991	*008	*024	*040	*056	*072	*088	*104	*120	6 | 10.2
											7 | 11.9
270	43 136	152	169	185	201	217	233	249	265	281	8 | 13.6
271	297	313	329	345	361	377	393	409	425	441	9 | 15.3
272	457	473	489	505	521	537	553	569	584	600	
273	616	632	648	664	680	696	712	727	743	759	**16**
274	775	791	807	823	838	854	870	886	902	917	1 | 1.6
275	933	949	965	981	996	*012	*028	*044	*059	*075	2 | 3.2
276	44 091	107	122	138	154	170	185	201	217	232	3 | 4.8
277	248	264	279	295	311	326	342	358	373	389	4 | 6.4
278	404	420	436	451	467	483	498	514	529	545	5 | 8.0
279	560	576	592	607	623	638	654	669	685	700	6 | 9.6
											7 | 11.2
280	716	731	747	762	778	793	809	824	840	855	8 | 12.8
281	871	886	902	917	932	948	963	979	994	*010	9 | 14.4
282	45 025	040	056	071	086	102	117	133	148	163	
283	179	194	209	225	240	255	271	286	301	317	**15**
284	332	347	362	378	393	408	423	439	454	469	1 | 1.5
285	484	500	515	530	545	561	576	591	606	621	2 | 3.0
286	637	652	667	682	697	712	728	743	758	773	3 | 4.5
287	788	803	818	834	849	864	879	894	909	924	4 | 6.0
288	939	954	969	984	*000	*015	*030	*045	*060	*075	5 | 7.5
289	46 090	105	120	135	150	165	180	195	210	225	6 | 9.0
											7 | 10.5
290	240	255	270	285	300	315	330	345	359	374	8 | 12.0
291	389	404	419	434	449	464	479	494	509	523	9 | 13.5
292	538	553	568	583	598	613	627	642	657	672	
293	687	702	716	731	746	761	776	790	805	820	**14**
294	835	850	864	879	894	909	923	938	953	967	1 | 1.4
295	982	997	*012	*026	*041	*056	*070	*085	*100	*114	2 | 2.8
296	47 129	144	159	173	188	202	217	232	246	261	3 | 4.2
297	276	290	305	319	334	349	363	378	392	407	4 | 5.6
298	422	436	451	465	480	494	509	524	538	553	5 | 7.0
299	567	582	596	611	625	640	654	669	683	698	6 | 8.4
											7 | 9.8
300	712	727	741	756	770	784	799	813	828	842	8 | 11.2
											9 | 12.6
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N.	L 0	1	2	3	4	5	6	7	8	9	P. P.
300	47 712	727	741	756	770	784	799	813	828	842	
301	857	871	885	900	914	929	943	958	972	986	
302	48 001	015	029	044	058	073	087	101	116	130	
303	144	159	173	187	202	216	230	244	259	273	
304	287	302	316	330	344	359	373	387	401	416	
305	430	444	458	473	487	501	515	530	544	558	**15**
306	572	586	601	615	629	643	657	671	686	700	1 1.5
307	714	728	742	756	770	785	799	813	827	841	2 3.0
308	855	869	883	897	911	926	940	954	968	982	3 4.5
309	996	*010	*024	*038	*052	*066	*080	*094	*108	*122	4 6.0
310	49 136	150	164	178	192	206	220	234	248	262	5 7.5
311	276	290	304	318	332	346	360	374	388	402	6 9.0
312	415	429	443	457	471	485	499	513	527	541	7 10.5
313	554	568	582	596	610	624	638	651	665	679	8 12.0
314	693	707	721	734	748	762	776	790	803	817	9 13.5
315	831	845	859	872	886	900	914	927	941	955	
316	969	982	996	*010	*024	*037	*051	*065	*079	*092	**14**
317	50 106	120	133	147	161	174	188	202	215	229	1 1.4
318	243	256	270	284	297	311	325	338	352	365	2 2.8
319	379	393	406	420	433	447	461	474	488	501	3 4.2
320	515	529	542	556	569	583	596	610	623	637	4 5.6
321	651	664	678	691	705	718	732	745	759	772	5 7.0
322	786	799	813	826	840	853	866	880	893	907	6 8.4
323	920	934	947	961	974	987	*001	*014	*028	*041	7 9.8
324	51 055	068	081	095	108	121	135	148	162	175	8 11.2
325	188	202	215	228	242	255	268	282	295	308	9 12.6
326	322	335	348	362	375	388	402	415	428	441	
327	455	468	481	495	508	521	534	548	561	574	**13**
328	587	601	614	627	640	654	667	680	693	706	1 1.3
329	720	733	746	759	772	786	799	812	825	838	2 2.6
330	851	865	878	891	904	917	930	943	957	970	3 3.9
331	983	996	*009	*022	*035	*048	*061	*075	*088	*101	4 5.2
332	52 114	127	140	153	166	179	192	205	218	231	5 6.5
333	244	257	270	284	297	310	323	336	349	362	6 7.8
334	375	388	401	414	427	440	453	466	479	492	7 9.1
335	504	517	530	543	556	569	582	595	608	621	8 10.4
336	634	647	660	673	686	699	711	724	737	750	9 11.7
337	763	776	789	802	815	827	840	853	866	879	
338	892	905	917	930	943	956	969	982	994	*007	**12**
339	53 020	033	046	058	071	084	097	110	122	135	1 1.2
340	148	161	173	186	199	212	224	237	250	263	2 2.4
341	275	288	301	314	326	339	352	364	377	390	3 3.6
342	403	415	428	441	453	466	479	491	504	517	4 4.8
343	529	542	555	567	580	593	605	618	631	643	5 6.0
344	656	668	681	694	706	719	732	744	757	769	6 7.2
345	782	794	807	820	832	845	857	870	882	895	7 8.4
346	908	920	933	945	958	970	983	995	*008	*020	8 9.6
347	54 033	045	058	070	083	095	108	120	133	145	9 10.8
348	158	170	183	195	208	220	233	245	258	270	
349	283	295	307	320	332	345	357	370	382	394	
350	407	419	432	444	456	469	481	494	506	518	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
350	54 407	419	432	444	456	469	481	494	506	518	
351	531	543	555	568	580	593	605	617	630	642	
352	654	667	679	691	704	716	728	741	753	765	
353	777	790	802	814	827	839	851	864	876	888	
354	900	913	925	937	949	962	974	986	998	*011	**13**
355	55 023	035	047	060	072	084	096	108	121	133	1 1.3
356	145	157	169	182	194	206	218	230	242	255	2 2.6
357	267	279	291	303	315	328	340	352	364	376	3 3.9
358	388	400	413	425	437	449	461	473	485	497	4 5.2
359	509	522	534	546	558	570	582	594	606	618	5 6.5
360	630	642	654	666	678	691	703	715	727	739	6 7.8
361	751	763	775	787	799	811	823	835	847	859	7 9.1
362	871	883	895	907	919	931	943	955	967	979	8 10.4
363	991	*003	*015	*027	*038	*050	*062	*074	*086	*098	9 11.7
364	56 110	122	134	146	158	170	182	194	205	217	
365	229	241	253	265	277	289	301	312	324	336	
366	348	360	372	384	396	407	419	431	443	455	**12**
367	467	478	490	502	514	526	538	549	561	573	1 1.2
368	585	597	608	620	632	644	656	667	679	691	2 2.4
369	703	714	726	738	750	761	773	785	797	808	3 3.6
370	820	832	844	855	867	879	891	902	914	926	4 4.8
371	937	949	961	972	984	996	*008	*019	*031	*043	5 6.0
372	57 054	066	078	089	101	113	124	136	148	159	6 7.2
373	171	183	194	206	217	229	241	252	264	276	7 8.4
374	287	299	310	322	334	345	357	368	380	392	8 9.6
375	403	415	426	438	449	461	473	484	496	507	9 10.8
376	519	530	542	553	565	576	588	600	611	623	
377	634	646	657	669	680	692	703	715	726	738	
378	749	761	772	784	795	807	818	830	841	852	**11**
379	864	875	887	898	910	921	933	944	955	967	1 1.1
380	978	990	*001	*013	*024	*035	*047	*058	*070	*081	2 2.2
381	58 092	104	115	127	138	149	161	172	184	195	3 3.3
382	206	218	229	240	252	263	274	286	297	309	4 4.4
383	320	331	343	354	365	377	388	399	410	422	5 5.5
384	433	444	456	467	478	490	501	512	524	535	6 6.6
385	546	557	569	580	591	602	614	625	636	647	7 7.7
386	659	670	681	692	704	715	726	737	749	760	8 8.8
387	771	782	794	805	816	827	838	850	861	872	9 9.9
388	883	894	906	917	928	939	950	961	973	984	
389	995	*006	*017	*028	*040	*051	*062	*073	*084	*095	
390	59 106	118	129	140	151	162	173	184	195	207	**10**
391	218	229	240	251	262	273	284	295	306	318	1 1.0
392	329	340	351	362	373	384	395	406	417	428	2 2.0
393	439	450	461	472	483	494	506	517	528	539	3 3.0
394	550	561	572	583	594	605	616	627	638	649	4 4.0
395	660	671	682	693	704	715	726	737	748	759	5 5.0
396	770	780	791	802	813	824	835	846	857	868	6 6.0
397	879	890	901	912	923	934	945	956	966	977	7 7.0
398	988	999	*010	*021	*032	*043	*054	*065	*076	*086	8 8.0
399	60 097	108	119	130	141	152	163	173	184	195	9 9.0
400	206	217	228	239	249	260	271	282	293	304	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
400	60 206	217	228	239	249	260	271	282	293	304	
401	314	325	336	347	358	369	379	390	401	412	
402	423	433	444	455	466	477	487	498	509	520	
403	531	541	552	563	574	584	595	606	617	627	
404	638	649	660	670	681	692	703	713	724	735	
405	746	756	767	778	788	799	810	821	831	842	
406	853	863	874	885	895	906	917	927	938	949	
407	959	970	981	991	*002	*013	*023	*034	*045	*055	**11**
408	61 066	077	087	098	109	119	130	140	151	162	1 1.1
409	172	183	194	204	215	225	236	247	257	268	2 2.2
410	278	289	300	310	321	331	342	352	363	374	3 3.3
411	384	395	405	416	426	437	448	458	469	479	4 4.4
412	490	500	511	521	532	542	553	563	574	584	5 5.5
413	595	606	616	627	637	648	658	669	679	690	6 6.6
414	700	711	721	731	742	752	763	773	784	794	7 7.7
415	805	815	826	836	847	857	868	878	888	899	8 8.8
416	909	920	930	941	951	962	972	982	993	*003	9 9.9
417	62 014	024	034	045	055	066	076	086	097	107	
418	118	128	138	149	159	170	180	190	201	211	
419	221	232	242	252	263	273	284	294	304	315	
420	325	335	346	356	366	377	387	397	408	418	
421	428	439	449	459	469	480	490	500	511	521	
422	531	542	552	562	572	583	593	603	613	624	**10**
423	634	644	655	665	675	685	696	706	716	726	1 1.0
424	737	747	757	767	778	788	798	808	818	829	2 2.0
425	839	849	859	870	880	890	900	910	921	931	3 3.0
426	941	951	961	972	982	992	*002	*012	*022	*033	4 4.0
427	63 043	053	063	073	083	094	104	114	124	134	5 5.0
428	144	155	165	175	185	195	205	215	225	236	6 6.0
429	246	256	266	276	286	296	306	317	327	337	7 7.0
430	347	357	367	377	387	397	407	417	428	438	8 8.0
431	448	458	468	478	488	498	508	518	528	538	9 9.0
432	548	558	568	579	589	599	609	619	629	639	
433	649	659	669	679	689	699	709	719	729	739	
434	749	759	769	779	789	799	809	819	829	839	
435	849	859	869	879	889	899	909	919	929	939	
436	949	959	969	979	988	998	*008	*018	*028	*038	
437	64 048	058	068	078	088	098	108	118	128	137	
438	147	157	167	177	187	197	207	217	227	237	**9**
439	246	256	266	276	286	296	306	316	326	335	1 0.9
440	345	355	365	375	385	395	404	414	424	434	2 1.8
441	444	454	464	473	483	493	503	513	523	532	3 2.7
442	542	552	562	572	582	591	601	611	621	631	4 3.6
443	640	650	660	670	680	689	699	709	719	729	5 4.5
444	738	748	758	768	777	787	797	807	816	826	6 5.4
445	836	846	856	865	875	885	895	904	914	924	7 6.3
446	933	943	953	963	972	982	992	*002	*011	*021	8 7.2
447	65 031	040	050	060	070	079	089	099	108	118	9 8.1
448	128	137	147	157	167	176	186	196	205	215	
449	225	234	244	254	263	273	283	292	302	312	
450	321	331	341	350	360	369	379	389	398	408	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
450	65 321	331	341	350	360	369	379	389	398	408	
451	418	427	437	447	456	466	475	485	495	504	
452	514	523	533	543	552	562	571	581	591	600	
453	610	619	629	639	648	658	667	677	686	696	
454	706	715	725	734	744	753	763	772	782	792	
455	801	811	820	830	839	849	858	868	877	887	
456	896	906	916	925	935	944	954	963	973	982	10
457	992	*001	*011	*020	*030	*039	*049	*058	*068	*077	1 1.0
458	66 087	096	106	115	124	134	143	153	162	172	2 2.0
459	181	191	200	210	219	229	238	247	257	266	3 3.0
460	276	285	295	304	314	323	332	342	351	361	4 4.0
461	370	380	389	398	408	417	427	436	445	455	5 5.0
462	464	474	483	492	502	511	521	530	539	549	6 6.0
463	558	567	577	586	596	605	614	624	633	642	7 7.0
464	652	661	671	680	689	699	708	717	727	736	8 8.0
465	745	755	764	773	783	792	801	811	820	829	9 9.0
466	839	848	857	867	876	885	894	904	913	922	
467	932	941	950	960	969	978	987	997	*006	*015	
468	67 025	034	043	052	062	071	080	089	099	108	
469	117	127	136	145	154	164	173	182	191	201	
470	210	219	228	237	247	256	265	274	284	293	
471	302	311	321	330	339	348	357	367	376	385	
472	394	403	413	422	431	440	449	459	468	477	9
473	486	495	504	514	523	532	541	550	560	569	1 0.9
474	578	587	596	605	614	624	633	642	651	660	2 1.8
475	669	679	688	697	706	715	724	733	742	752	3 2.7
476	761	770	779	788	797	806	815	825	834	843	4 3.6
477	852	861	870	879	888	897	906	916	925	934	5 4.5
478	943	952	961	970	979	988	997	*006	*015	*024	6 5.4
479	68 034	043	052	061	070	079	088	097	106	115	7 6.3
480	124	133	142	151	160	169	178	187	196	205	8 7.2
481	215	224	233	242	251	260	269	278	287	296	9 8.1
482	305	314	323	332	341	350	359	368	377	386	
483	395	404	413	422	431	440	449	458	467	476	
484	485	494	502	511	520	529	538	547	556	565	
485	574	583	592	601	610	619	628	637	646	655	
486	664	673	681	690	699	708	717	726	735	744	
487	753	762	771	780	789	797	806	815	824	833	8
488	842	851	860	869	878	886	895	904	913	922	1 0.8
489	931	940	949	958	966	975	984	993	*002	*011	2 1.6
490	69 020	028	037	046	055	064	073	082	090	099	3 2.4
491	108	117	126	135	144	152	161	170	179	188	4 3.2
492	197	205	214	223	232	241	249	258	267	276	5 4.0
493	285	294	302	311	320	329	338	346	355	364	6 4.8
494	373	381	390	399	408	417	425	434	443	452	7 5.6
495	461	469	478	487	496	504	513	522	531	539	8 6.4
496	548	557	566	574	583	592	601	609	618	627	9 7.2
497	636	644	653	662	671	679	688	697	705	714	
498	723	732	740	749	758	767	775	784	793	801	
499	810	819	827	836	845	854	862	871	880	888	
500	897	906	914	923	932	940	949	958	966	975	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
500	69 897	906	914	923	932	940	949	958	966	975	
501	984	992	*001	*010	*018	*027	*036	*044	*053	*062	
502	70 070	079	088	096	105	114	122	131	140	148	
503	157	165	174	183	191	200	209	217	226	234	
504	243	252	260	269	278	286	295	303	312	321	
505	329	338	346	355	364	372	381	389	398	406	
506	415	424	432	441	449	458	467	475	484	492	
507	501	509	518	526	535	544	552	561	569	578	9
508	586	595	603	612	621	629	638	646	655	663	1 | 0.9
509	672	680	689	697	706	714	723	731	740	749	2 | 1.8
510	757	766	774	783	791	800	808	817	825	834	3 | 2.7
511	842	851	859	868	876	885	893	902	910	919	4 | 3.6
512	927	935	944	952	961	969	978	986	995	*003	5 | 4.5
513	71 012	020	029	037	046	054	063	071	079	088	6 | 5.4
514	096	105	113	122	130	139	147	155	164	172	7 | 6.3
515	181	189	198	206	214	223	231	240	248	257	8 | 7.2
516	265	273	282	290	299	307	315	324	332	341	9 | 8.1
517	349	357	366	374	383	391	399	408	416	425	
518	433	441	450	458	466	475	483	492	500	508	
519	517	525	533	542	550	559	567	575	584	592	
520	600	609	617	625	634	642	650	659	667	675	
521	684	692	700	709	717	725	734	742	750	759	
522	767	775	784	792	800	809	817	825	834	842	
523	850	858	867	875	883	892	900	908	917	925	8
524	933	941	950	958	966	975	983	991	999	*008	1 | 0.8
525	72 016	024	032	041	049	057	066	074	082	090	2 | 1.6
526	099	107	115	123	132	140	148	156	165	173	3 | 2.4
527	181	189	198	206	214	222	230	239	247	255	4 | 3.2
528	263	272	280	288	296	304	313	321	329	337	5 | 4.0
529	346	354	362	370	378	387	395	403	411	419	6 | 4.8
530	428	436	444	452	460	469	477	485	493	501	7 | 5.6
531	509	518	526	534	542	550	558	567	575	583	8 | 6.4
532	591	599	607	616	624	632	640	648	656	665	9 | 7.2
533	673	681	689	697	705	713	722	730	738	746	
534	754	762	770	779	787	795	803	811	819	827	
535	835	843	852	860	868	876	884	892	900	908	
536	916	925	933	941	949	957	965	973	981	989	
537	997	*006	*014	*022	*030	*038	*046	*054	*062	*070	7
538	73 078	086	094	102	111	119	127	135	143	151	1 | 0.7
539	159	167	175	183	191	199	207	215	223	231	2 | 1.4
540	239	247	255	263	272	280	288	296	304	312	3 | 2.1
541	320	328	336	344	352	360	368	376	384	392	4 | 2.8
542	400	408	416	424	432	440	448	456	464	472	5 | 3.5
543	480	488	496	504	512	520	528	536	544	552	6 | 4.2
544	560	568	576	584	592	600	608	616	624	632	7 | 4.9
545	640	648	656	664	672	679	687	695	703	711	8 | 5.6
546	719	727	735	743	751	759	767	775	783	791	9 | 6.3
547	799	807	815	823	830	838	846	854	862	870	
548	878	886	894	902	910	918	926	933	941	949	
549	957	965	973	981	989	997	*005	*013	*020	*028	
550	74 036	044	052	060	068	076	084	092	099	107	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
550	74 036	044	052.	060	068	076	084	092	099	107	
551	115	123	131	139	147	155	162	170	178	186	
552	194	202	210	218	225	233	241	249	257	265	
553	273	280	288	296	304	312	320	327	335	343	
554	351	359	367	374	382	390	398	406	414	421	
555	429	437	445	453	461	468	476	484	492	500	
556	507	515	523	531	539	547	554	562	570	578	
557	586	593	601	609	617	624	632	640	648	656	
558	663	671	679	687	695	702	710	718	726	733	
559	741	749	757	764	772	780	788	796	803	811	
560	819	827	834	842	850	858	865	873	881	889	**8**
561	896	904	912	920	927	935	943	950	958	966	1 0.8
562	974	981	989	997	*005	*012	*020	*028	*035	*043	2 1.6
563	75 051	059	066	074	082	089	097	105	113	120	3 2.4
564	128	136	143	151	159	166	174	182	189	197	4 3.2
565	205	213	220	228	236	243	251	259	266	274	5 4.0
566	282	289	297	305	312	320	328	335	343	351	6 4.8
567	358	366	374	381	389	397	404	412	420	427	7 5.6
568	435	442	450	458	465	473	481	488	496	504	8 6.4
569	511	519	526	534	542	549	557	565	572	580	9 7.2
570	587	595	603	610	618	626	633	641	648	656	
571	664	671	679	686	694	702	709	717	724	732	
572	740	747	755	762	770	778	785	793	800	808	
573	815	823	831	838	846	853	861	868	876	884	
574	891	899	906	914	921	929	937	944	952	959	
575	967	974	982	989	997	*005	*012	*020	*027	*035	
576	76 042	050	057	065	072	080	087	095	103	110	
577	118	125	133	140	148	155	163	170	178	185	
578	193	200	208	215	223	230	238	245	253	260	
579	268	275	283	290	298	305	313	320	328	335	
580	343	350	358	365	373	380	388	395	403	410	
581	418	425	433	440	448	455	462	470	477	485	
582	492	500	507	515	522	530	537	545	552	559	
583	567	574	582	589	597	604	612	619	626	634	
584	641	649	656	664	671	678	686	693	701	708	**7**
585	716	723	730	738	745	753	760	768	775	782	1 0.7
586	790	797	805	812	819	827	834	842	849	856	2 1.4
587	864	871	879	886	893	901	908	916	923	930	3 2.1
588	938	945	953	960	967	975	982	989	997	*004	4 2.8
589	77 012	019	026	034	041	048	056	063	070	078	5 3.5
590	085	093	100	107	115	122	129	137	144	151	6 4.2
591	159	166	173	181	188	195	203	210	217	225	7 4.9
592	232	240	247	254	262	269	276	283	291	298	8 5.6
593	305	313	320	327	335	342	349	357	364	371	9 6.3
594	379	386	393	401	408	415	422	430	437	444	
595	452	459	466	474	481	488	495	503	510	517	
596	525	532	539	546	554	561	568	576	583	590	
597	597	605	612	619	627	634	641	648	656	663	
598	670	677	685	692	699	706	714	721	728	735	
599	743	750	757	764	772	779	786	793	801	808	
600	815	822	830	837	844	851	859	866	873	880	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
600	77 815	822	830	837	844	851	859	866	873	880	
601	887	895	902	909	916	924	931	938	945	952	
602	960	967	974	981	988	996	*003	*010	*017	*025	
603	78 032	039	046	053	061	068	075	082	089	097	
604	104	111	118	125	132	140	147	154	161	168	
605	176	183	190	197	204	211	219	226	233	240	
606	247	254	262	269	276	283	290	297	305	312	
607	319	326	333	340	347	355	362	369	376	383	8
608	390	398	405	412	419	426	433	440	447	455	1 0.8
609	462	469	476	483	490	497	504	512	519	526	2 1.6
610	533	540	547	554	561	569	576	583	590	597	3 2.4
611	604	611	618	625	633	640	647	654	661	668	4 3.2
612	675	682	689	696	704	711	718	725	732	739	5 4.0
613	746	753	760	767	774	781	789	796	803	810	6 4.8
614	817	824	831	838	845	852	859	866	873	880	7 5.6
615	888	895	902	909	916	923	930	937	944	951	8 6.4
616	958	965	972	979	986	993	*000	*007	*014	*021	9 7.2
617	79 029	036	043	050	057	064	071	078	085	092	
618	099	106	113	120	127	134	141	148	155	162	
619	169	176	183	190	197	204	211	218	225	232	
620	239	246	253	260	267	274	281	288	295	302	
621	309	316	323	330	337	344	351	358	365	372	
622	379	386	393	400	407	414	421	428	435	442	7
623	449	456	463	470	477	484	491	498	505	511	1 0.7
624	518	525	532	539	546	553	560	567	574	581	2 1.4
625	588	595	602	609	616	623	630	637	644	650	3 2.1
626	657	664	671	678	685	692	699	706	713	720	4 2.8
627	727	734	741	748	754	761	768	775	782	789	5 3.5
628	796	803	810	817	824	831	837	844	851	858	6 4.2
629	865	872	879	886	893	900	906	913	920	927	7 4.9
630	934	941	948	955	962	969	975	982	989	996	8 5.6
631	80 003	010	017	024	030	037	044	051	058	065	9 6.3
632	072	079	085	092	099	106	113	120	127	134	
633	140	147	154	161	168	175	182	188	195	202	
634	209	216	223	229	236	243	250	257	264	271	
635	277	284	291	298	305	312	318	325	332	339	
636	346	353	359	366	373	380	387	393	400	407	
637	414	421	428	434	441	448	455	462	468	475	
638	482	489	496	502	509	516	523	530	536	543	6
639	550	557	564	570	577	584	591	598	604	611	1 0.6
640	618	625	632	638	645	652	659	665	672	679	2 1.2
641	686	693	699	706	713	720	726	733	740	747	3 1.8
642	754	760	767	774	781	787	794	801	808	814	4 2.4
643	821	828	835	841	848	855	862	868	875	882	5 3.0
644	889	895	902	909	916	922	929	936	943	949	6 3.6
645	956	963	969	976	983	990	996	*003	*010	*017	7 4.2
646	81 023	030	037	043	050	057	064	070	077	084	8 4.8
647	090	097	104	111	117	124	131	137	144	151	9 5.4
648	158	164	171	178	184	191	198	204	211	218	
649	224	231	238	245	251	258	265	271	278	285	
650	291	298	305	311	318	325	331	338	345	351	
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N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
650	81 291	298	305	311	318	325	331	338	345	351	
651	358	365	371	378	385	391	398	405	411	418	
652	425	431	438	445	451	458	465	471	478	485	
653	491	498	505	511	518	525	531	538	544	551	
654	558	564	571	578	584	591	598	604	611	617	
655	624	631	637	644	651	657	664	671	677	684	
656	690	697	704	710	717	723	730	737	743	750	
657	757	763	770	776	783	790	796	803	809	816	
658	823	829	836	842	849	856	862	869	875	882	
659	889	895	902	908	915	921	928	935	941	948	
660	954	961	968	974	981	987	994	*000	*007	*014	**7**
661	82 020	027	033	040	046	053	060	066	073	079	1 0.7
662	086	092	099	105	112	119	125	132	138	145	2 1.4
663	151	158	164	171	178	184	191	197	204	210	3 2.1
664	217	223	230	236	243	249	256	263	269	276	4 2.8
665	282	289	295	302	308	315	321	328	334	341	5 3.5
666	347	354	360	367	373	380	387	393	400	406	6 4.2
667	413	419	426	432	439	445	452	458	465	471	7 4.9
668	478	484	491	497	504	510	517	523	530	536	8 5.6
669	543	549	556	562	569	575	582	588	595	601	9 6.3
670	607	614	620	627	633	640	646	653	659	666	
671	672	679	685	692	698	705	711	718	724	730	
672	737	743	750	756	763	769	776	782	789	795	
673	802	808	814	821	827	834	840	847	853	860	
674	866	872	879	885	892	898	905	911	918	924	
675	930	937	943	950	956	963	969	975	982	988	
676	995	*001	*008	*014	*020	*027	*033	*040	*046	*052	
677	83 059	065	072	078	085	091	097	104	110	117	
678	123	129	136	142	149	155	161	168	174	181	
679	187	193	200	206	213	219	225	232	238	245	
680	251	257	264	270	276	283	289	296	302	308	
681	315	321	327	334	340	347	353	359	366	372	
682	378	385	391	398	404	410	417	423	429	436	
683	442	448	455	461	467	474	480	487	493	499	
684	506	512	518	525	531	537	544	550	556	563	**6**
685	569	575	582	588	594	601	607	613	620	626	1 0.6
686	632	639	645	651	658	664	670	677	683	689	2 1.2
687	696	702	708	715	721	727	734	740	746	753	3 1.8
688	759	765	771	778	784	790	797	803	809	816	4 2.4
689	822	828	835	841	847	853	860	866	872	879	5 3.0
690	885	891	897	904	910	916	923	929	935	942	6 3.6
691	948	954	960	967	973	979	985	992	998	*004	7 4.2
692	84 011	017	023	029	036	042	048	055	061	067	8 4.8
693	073	080	086	092	098	105	111	117	123	130	9 5.4
694	136	142	148	155	161	167	173	180	186	192	
695	198	205	211	217	223	230	236	242	248	255	
696	261	267	273	280	286	292	298	305	311	317	
697	323	330	336	342	348	354	361	367	373	379	
698	386	392	398	404	410	417	423	429	435	442	
699	448	454	460	466	473	479	485	491	497	504	
700	510	516	522	528	535	541	547	553	559	566	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
700	84 510	516	522	528	535	541	547	553	559	566	
701	572	578	584	590	597	603	609	615	621	628	
702	634	640	646	652	658	665	671	677	683	689	
703	696	702	708	714	720	726	733	739	745	751	
704	757	763	770	776	782	788	794	800	807	813	
705	819	825	831	837	844	850	856	862	868	874	
706	880	887	893	899	905	911	917	924	930	936	
707	942	948	954	960	967	973	979	985	991	997	**7**
708	85 003	009	016	022	028	034	040	046	052	058	1 | 0.7
709	065	071	077	083	089	095	101	107	114	120	2 | 1.4
710	126	132	138	144	150	156	163	169	175	181	3 | 2.1
711	187	193	199	205	211	217	224	230	236	242	4 | 2.8
712	248	254	260	266	272	278	285	291	297	303	5 | 3.5
713	309	315	321	327	333	339	345	352	358	364	6 | 4.2
714	370	376	382	388	394	400	406	412	418	425	7 | 4.9
715	431	437	443	449	455	461	467	473	479	485	8 | 5.6
716	491	497	503	509	516	522	528	534	540	546	9 | 6.3
717	552	558	564	570	576	582	588	594	600	606	
718	612	618	625	631	637	643	649	655	661	667	
719	673	679	685	691	697	703	709	715	721	727	
720	733	739	745	751	757	763	769	775	781	788	
721	794	800	806	812	818	824	830	836	842	848	
722	854	860	866	872	878	884	890	896	902	908	**6**
723	914	920	926	932	938	944	950	956	962	968	1 | 0.6
724	974	980	986	992	998	*004	*010	*016	*022	*028	2 | 1.2
725	86 034	040	046	052	058	064	070	076	082	088	3 | 1.8
726	094	100	106	112	118	124	130	136	141	147	4 | 2.4
727	153	159	165	171	177	183	189	195	201	207	5 | 3.0
728	213	219	225	231	237	243	249	255	261	267	6 | 3.6
729	273	279	285	291	297	303	308	314	320	326	7 | 4.2
730	332	338	344	350	356	362	368	374	380	386	8 | 4.8
731	392	398	404	410	415	421	427	433	439	445	9 | 5.4
732	451	457	463	469	475	481	487	493	499	504	
733	510	516	522	528	534	540	546	552	558	564	
734	570	576	581	587	593	599	605	611	617	623	
735	629	635	641	646	652	658	664	670	676	682	
736	688	694	700	705	711	717	723	729	735	741	
737	747	753	759	764	770	776	782	788	794	800	**5**
738	806	812	817	823	829	835	841	847	853	859	1 | 0.5
739	864	870	876	882	888	894	900	906	911	917	2 | 1.0
740	923	929	935	941	947	953	958	964	970	976	3 | 1.5
741	982	988	994	999	*005	*011	*017	*023	*029	*035	4 | 2.0
742	87 040	046	052	058	064	070	075	081	087	093	5 | 2.5
743	099	105	111	116	122	128	134	140	146	151	6 | 3.0
744	157	163	169	175	181	186	192	198	204	210	7 | 3.5
745	216	221	227	233	239	245	251	256	262	268	8 | 4.0
746	274	280	286	291	297	303	309	315	320	326	9 | 4.5
747	332	338	344	349	355	361	367	373	379	384	
748	390	396	402	408	413	419	425	431	437	442	
749	448	454	460	466	471	477	483	489	495	500	
750	506	512	518	523	529	535	541	547	552	558	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P
750	87 506	512	518	523	529	535	541	547	552	558	
751	564	570	576	581	587	593	599	604	610	616	
752	622	628	633	639	645	651	656	662	668	674	
753	679	685	691	697	703	708	714	720	726	731	
754	737	743	749	754	760	766	772	777	783	789	
755	795	800	806	812	818	823	829	835	841	846	
756	852	858	864	869	875	881	887	892	898	904	
757	910	915	921	927	933	938	944	950	955	961	
758	967	973	978	984	990	996	*001	*007	*013	*018	
759	88 024	030	036	041	047	053	058	064	070	076	
760	081	087	093	098	104	110	116	121	127	133	
761	138	144	150	156	161	167	173	178	184	190	
762	195	201	207	213	218	224	230	235	241	247	**6**
763	252	258	264	270	275	281	287	292	298	304	1 | 0.6
764	309	315	321	326	332	338	343	349	355	360	2 | 1.2
765	366	372	377	383	389	395	400	406	412	417	3 | 1.8
766	423	429	434	440	446	451	457	463	468	474	4 | 2.4
767	480	485	491	497	502	508	513	519	525	530	5 | 3.0
768	536	542	547	553	559	564	570	576	581	587	6 | 3.6
769	593	598	604	610	615	621	627	632	638	643	7 | 4.2
770	649	655	660	666	672	677	683	689	694	700	8 | 4.8
771	705	711	717	722	728	734	739	745	750	756	9 | 5.4
772	762	767	773	779	784	790	795	801	807	812	
773	818	824	829	835	840	846	852	857	863	868	
774	874	880	885	891	897	902	908	913	919	925	
775	930	936	941	947	953	958	964	969	975	981	
776	986	992	997	*003	*009	*014	*020	*025	*031	*037	
777	89 042	048	053	059	064	070	076	081	087	092	
778	098	104	109	115	120	126	131	137	143	148	
779	154	159	165	170	176	182	187	193	198	204	
780	209	215	221	226	232	237	243	248	254	260	
781	265	271	276	282	287	293	298	304	310	315	
782	321	326	332	337	343	348	354	360	365	371	**5**
783	376	382	387	393	398	404	409	415	421	426	1 | 0.5
784	432	437	443	448	454	459	465	470	476	481	2 | 1.0
785	487	492	498	504	509	515	520	526	531	537	3 | 1.5
786	542	548	553	559	564	570	575	581	586	592	4 | 2.0
787	597	603	609	614	620	625	631	636	642	647	5 | 2.5
788	653	658	664	669	675	680	686	691	697	702	6 | 3.0
789	708	713	719	724	730	735	741	746	752	757	7 | 3.5
790	763	768	774	779	785	790	796	801	807	812	8 | 4.0
791	818	823	829	834	840	845	851	856	862	867	9 | 4.5
792	873	878	883	889	894	900	905	911	916	922	
793	927	933	938	944	949	955	960	966	971	977	
794	982	988	993	998	*004	*009	*015	*020	*026	*031	
795	90 037	042	048	053	059	064	069	075	080	086	
796	091	097	102	108	113	119	124	129	135	140	
797	146	151	157	162	168	173	179	184	189	195	
798	200	206	211	217	222	227	233	238	244	249	
799	255	260	266	271	276	282	287	293	298	304	
800	309	314	320	325	331	336	342	347	352	358	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
800	90 309	314	320	325	331	336	342	347	352	358	
801	363	369	374	380	385	390	396	401	407	412	
802	417	423	428	434	439	445	450	455	461	466	
803	472	477	482	488	493	499	504	509	515	520	
804	526	531	536	542	547	553	558	563	569	574	
805	580	585	590	596	601	607	612	617	623	628	
806	634	639	644	650	655	660	666	671	677	682	
807	687	693	698	703	709	714	720	725	730	736	
808	741	747	752	757	763	768	773	779	784	789	
809	795	800	806	811	816	822	827	832	838	843	
810	849	854	859	865	870	875	881	886	891	897	
811	902	907	913	918	924	929	934	940	945	950	
812	956	961	966	972	977	982	988	993	998	*004	**6**
813	91 009	014	020	025	030	036	041	046	052	057	1 | 0.6
814	062	068	073	078	084	089	094	100	105	110	2 | 1.2
815	116	121	126	132	137	142	148	153	158	164	3 | 1.8
816	169	174	180	185	190	196	201	206	212	217	4 | 2.4
817	222	228	233	238	243	249	254	259	265	270	5 | 3.0
818	275	281	286	291	297	302	307	312	318	323	6 | 3.6
819	328	334	339	344	350	355	360	365	371	376	7 | 4.2
820	381	387	392	397	403	408	413	418	424	429	8 | 4.8
821	434	440	445	450	455	461	466	471	477	482	9 | 5.4
822	487	492	498	503	508	514	519	524	529	535	
823	540	545	551	556	561	566	572	577	582	587	
824	593	598	603	609	614	619	624	630	635	640	
825	645	651	656	661	666	672	677	682	687	693	
826	698	703	709	714	719	724	730	735	740	745	
827	751	756	761	766	772	777	782	787	793	798	
828	803	808	814	819	824	829	834	840	845	850	
829	855	861	866	871	876	882	887	892	897	903	
830	908	913	918	924	929	934	939	944	950	955	
831	960	965	971	976	981	986	991	997	*002	*007	**5**
832	92 012	018	023	028	033	038	044	049	054	059	1 | 0.5
833	065	070	075	080	085	091	096	101	106	111	2 | 1.0
834	117	122	127	132	137	143	148	153	158	163	3 | 1.5
835	169	174	179	184	189	195	200	205	210	215	4 | 2.0
836	221	226	231	236	241	247	252	257	262	267	5 | 2.5
837	273	278	283	288	293	298	304	309	314	319	6 | 3.0
838	324	330	335	340	345	350	355	361	366	371	7 | 3.5
839	376	381	387	392	397	402	407	412	418	423	8 | 4.0
840	428	433	438	443	449	454	459	464	469	474	9 | 4.5
841	480	485	490	495	500	505	511	516	521	526	
842	531	536	542	547	552	557	562	567	572	578	
843	583	588	593	598	603	609	614	619	624	629	
844	634	639	645	650	655	660	665	670	675	681	
845	686	691	696	701	706	711	716	722	727	732	
846	737	742	747	752	758	763	768	773	778	783	
847	788	793	799	804	809	814	819	824	829	834	
848	840	845	850	855	860	865	870	875	881	886	
849	891	896	901	906	911	916	921	927	932	937	
850	942	947	952	957	962	967	973	978	983	988	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
850	92 942	947	952	957	962	967	973	978	983	988	
851	993	998	*003	*008	*013	*018	*024	*029	*034	*039	
852	93 044	049	054	059	064	069	075	080	085	090	
853	095	100	105	110	115	120	125	131	136	141	
854	146	151	156	161	166	171	176	181	186	192	
855	197	202	207	212	217	222	227	232	237	242	
856	247	252	258	263	268	273	278	283	288	293	
857	298	303	308	313	318	323	328	334	339	344	**6**
858	349	354	359	364	369	374	379	384	389	394	1 | 0.6
859	399	404	409	414	420	425	430	435	440	445	2 | 1.2
860	450	455	460	465	470	475	480	485	490	495	3 | 1.8
861	500	505	510	515	520	526	531	536	541	546	4 | 2.4
862	551	556	561	566	571	576	581	586	591	596	5 | 3.0
863	601	606	611	616	621	626	631	636	641	646	6 | 3.6
864	651	656	661	666	671	676	682	687	692	697	7 | 4.2
865	702	707	712	717	722	727	732	737	742	747	8 | 4.8
866	752	757	762	767	772	777	782	787	792	797	9 | 5.4
867	802	807	812	817	822	827	832	837	842	847	
868	852	857	862	867	872	877	882	887	892	897	
869	902	907	912	917	922	927	932	937	942	947	
870	952	957	962	967	972	977	982	987	992	997	
871	94 002	007	012	017	022	027	032	037	042	047	
872	052	057	062	067	072	077	082	086	091	096	**5**
873	101	106	111	116	121	126	131	136	141	146	1 | 0.5
874	151	156	161	166	171	176	181	186	191	196	2 | 1.0
875	201	206	211	216	221	226	231	236	240	245	3 | 1.5
876	250	255	260	265	270	275	280	285	290	295	4 | 2.0
877	300	305	310	315	320	325	330	335	340	345	5 | 2.5
878	349	354	359	364	369	374	379	384	389	394	6 | 3.0
879	399	404	409	414	419	424	429	433	438	443	7 | 3.5
880	448	453	458	463	468	473	478	483	488	493	8 | 4.0
881	498	503	507	512	517	522	527	532	537	542	9 | 4.5
882	547	552	557	562	567	571	576	581	586	591	
883	596	601	606	611	616	621	626	630	635	640	
884	645	650	655	660	665	670	675	680	685	689	
885	694	699	704	709	714	719	724	729	734	738	
886	743	748	753	758	763	768	773	778	783	787	
887	792	797	802	807	812	817	822	827	832	836	
888	841	846	851	856	861	866	871	876	880	885	**4**
889	890	895	900	905	910	915	919	924	929	934	1 | 0.4
890	939	944	949	954	959	963	968	973	978	983	2 | 0.8
891	988	993	998	*002	*007	*012	*017	*022	*027	*032	3 | 1.2
892	95 036	041	046	051	056	061	066	071	075	080	4 | 1.6
893	085	090	095	100	105	109	114	119	124	129	5 | 2.0
894	134	139	143	148	153	158	163	168	173	177	6 | 2.4
895	182	187	192	197	202	207	211	216	221	226	7 | 2.8
896	231	236	240	245	250	255	260	265	270	274	8 | 3.2
897	279	284	289	294	299	303	308	313	318	323	9 | 3.6
898	328	332	337	342	347	352	357	361	366	371	
899	376	381	386	390	395	400	405	410	415	419	
900	424	429	434	439	444	448	453	458	463	468	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
900	95 424	429	434	439	444	448	453	458	463	468	
901	472	477	482	487	492	497	501	506	511	516	
902	521	525	530	535	540	545	550	554	559	564	
903	569	574	578	583	588	593	598	602	607	612	
904	617	622	626	631	636	641	646	650	655	660	
905	665	670	674	679	684	689	694	698	703	708	
906	713	718	722	727	732	737	742	746	751	756	
907	761	766	770	775	780	785	789	794	799	804	
908	809	813	818	823	828	832	837	842	847	852	
909	856	861	866	871	875	880	885	890	895	899	
910	904	909	914	918	923	928	933	938	942	947	
911	952	957	961	966	971	976	980	985	990	995	**5**
912	999	*004	*009	*014	*019	*023	*028	*033	*038	*042	1 | 0.5
913	96 047	052	057	061	066	071	076	080	085	090	2 | 1.0
914	095	099	104	109	114	118	123	128	133	137	3 | 1.5
915	142	147	152	156	161	166	171	175	180	185	4 | 2.0
916	190	194	199	204	209	213	218	223	227	232	5 | 2.5
917	237	242	246	251	256	261	265	270	275	280	6 | 3.0
918	284	289	294	298	303	308	313	317	322	327	7 | 3.5
919	332	336	341	346	350	355	360	365	369	374	8 | 4.0
920	379	384	388	393	398	402	407	412	417	421	9 | 4.5
921	426	431	435	440	445	450	454	459	464	468	
922	473	478	483	487	492	497	501	506	511	515	
923	520	525	530	534	539	544	548	553	558	562	
924	567	572	577	581	586	591	595	600	605	609	
925	614	619	624	628	633	638	642	647	652	656	
926	661	666	670	675	680	685	689	694	699	703	
927	708	713	717	722	727	731	736	741	745	750	
928	755	759	764	769	774	778	783	788	792	797	
929	802	806	811	816	820	825	830	834	839	844	
930	848	853	858	862	867	872	876	881	886	890	
931	895	900	904	909	914	918	923	928	932	937	
932	942	946	951	956	960	965	970	974	979	984	
933	988	993	997	*002	*007	*011	*016	*021	*025	*030	
934	97 035	039	044	049	053	058	063	067	072	077	**4**
935	081	086	090	095	100	104	109	114	118	123	1 | 0.4
936	128	132	137	142	146	151	155	160	165	169	2 | 0.8
937	174	179	183	188	192	197	202	206	211	216	3 | 1.2
938	220	225	230	234	239	243	248	253	257	262	4 | 1.6
939	267	271	276	280	285	290	294	299	304	308	5 | 2.0
940	313	317	322	327	331	336	340	345	350	354	6 | 2.4
941	359	364	368	373	377	382	387	391	396	400	7 | 2.8
942	405	410	414	419	424	428	433	437	442	447	8 | 3.2
943	451	456	460	465	470	474	479	483	488	493	9 | 3.6
944	497	502	506	511	516	520	525	529	534	539	
945	543	548	552	557	562	566	571	575	580	585	
946	589	594	598	603	607	612	617	621	626	630	
947	635	640	644	649	653	658	663	667	672	676	
948	681	685	690	695	699	704	708	713	717	722	
949	727	731	736	740	745	749	754	759	763	768	
950	772	777	782	786	791	795	800	804	809	813	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
950	97 772	777	782	786	791	795	800	804	809	813	
951	818	823	827	832	836	841	845	850	855	859	
952	864	868	873	877	882	886	891	896	900	905	
953	909	914	918	923	928	932	937	941	946	950	
954	955	959	964	968	973	978	982	987	991	996	
955	98 000	005	009	014	019	023	028	032	037	041	
956	046	050	055	059	064	068	073	078	082	087	
957	091	096	100	105	109	114	118	123	127	132	
958	137	141	146	150	155	159	164	168	173	177	
959	182	186	191	195	200	204	209	214	218	223	
960	227	232	236	241	245	250	254	259	263	268	
961	272	277	281	286	290	295	299	304	308	313	**5**
962	318	322	327	331	336	340	345	349	354	358	1 | 0.5
963	363	367	372	376	381	385	390	394	399	403	2 | 1.0
964	408	412	417	421	426	430	435	439	444	448	3 | 1.5
965	453	457	462	466	471	475	480	484	489	493	4 | 2.0
966	498	502	507	511	516	520	525	529	534	538	5 | 2.5
967	543	547	552	556	561	565	570	574	579	583	6 | 3.0
968	588	592	597	601	605	610	614	619	623	628	7 | 3.5
969	632	637	641	646	650	655	659	664	668	673	8 | 4.0
970	677	682	686	691	695	700	704	709	713	717	9 | 4.5
971	722	726	731	735	740	744	749	753	758	762	
972	767	771	776	780	784	789	793	798	802	807	
973	811	816	820	825	829	834	838	843	847	851	
974	856	860	865	869	874	878	883	887	892	896	
975	900	905	909	914	918	923	927	932	936	941	
976	945	949	954	958	963	967	972	976	981	985	
977	989	994	998	*003	*007	*012	*016	*021	*025	*029	
978	99 034	038	043	047	052	056	061	065	069	074	
979	078	083	087	092	096	100	105	109	114	118	
980	123	127	131	136	140	145	149	154	158	162	
981	167	171	176	180	185	189	193	198	202	207	**4**
982	211	216	220	224	229	233	238	242	247	251	1 | 0.4
983	255	260	264	269	273	277	282	286	291	295	2 | 0.8
984	300	304	308	313	317	322	326	330	335	339	3 | 1.2
985	344	348	352	357	361	366	370	374	379	383	4 | 1.6
986	388	392	396	401	405	410	414	419	423	427	5 | 2.0
987	432	436	441	445	449	454	458	463	467	471	6 | 2.4
988	476	480	484	489	493	498	502	506	511	515	7 | 2.8
989	520	524	528	533	537	542	546	550	555	559	8 | 3.2
990	564	568	572	577	581	585	590	594	599	603	9 | 3.6
991	607	612	616	621	625	629	634	638	642	647	
992	651	656	660	664	669	673	677	682	686	691	
993	695	699	704	708	712	717	721	726	730	734	
994	739	743	747	752	756	760	765	769	774	778	
995	782	787	791	795	800	804	808	813	817	822	
996	826	830	835	839	843	848	852	856	861	865	
997	870	874	878	883	887	891	896	900	904	909	
998	913	917	922	926	930	935	939	944	948	952	
999	957	961	965	970	974	978	983	987	991	996	
1000	00 000	004	009	013	017	022	026	030	035	039	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

TABLES

OF

NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS

GIVING THE VALUES OF THE FUNCTIONS FOR ALL DEGREES AND MINUTES FROM 0° TO 90°

′	5°		6°		7°		8°		9°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	.15672	.98764	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	.15701	.98760	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	.15730	.98755	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	.15758	.98751	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	.15787	.98746	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	.15816	.98741	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	.15845	.98737	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	.15873	.98732	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	.15902	.98728	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	.15931	.98723	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	.15959	.98718	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	.15988	.98714	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	.16017	.98709	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	.16046	.98704	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	.16074	.98700	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	.16103	.98695	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	.16132	.98690	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	.16160	.98686	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	.16189	.98681	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	.16218	.98676	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	.16246	.98671	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	.16275	.98667	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	.16304	.98662	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	.16333	.98657	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	.16361	.98652	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	.16390	.98648	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	.16419	.98643	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	.16447	.98638	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	.16476	.98633	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	.16505	.98629	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	.16533	.98624	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	.16562	.98619	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	.16591	.98614	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	.16620	.98609	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	.16648	.98604	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	.16677	.98600	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	.16706	.98595	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	.16734	.98590	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	.16763	.98585	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	.16792	.98580	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	.16820	.98575	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	.16849	.98570	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	.16878	.98565	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	.16906	.98561	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	.16935	.98556	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	.16964	.98551	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	.16992	.98546	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	.17021	.98541	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	.17050	.98536	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	.17078	.98531	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	.17107	.98526	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	.17136	.98521	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	.17164	.98516	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	.17193	.98511	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	.17222	.98506	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	.17250	.98501	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	.17279	.98496	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	.17308	.98491	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	.17336	.98486	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	.17365	.98481	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	84°		83°		82°		81°		80°		

′	0°		1°		2°		3°		4°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.00000	1.	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.00029	1.	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.00058	1.	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.00087	1.	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.00116	1.	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.00145	1.	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.00175	1.	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.00204	1.	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.00233	1.	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.00262	1.	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.00291	1.	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.00320	.99999	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.00349	.99999	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.00378	.99999	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.00407	.99999	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.00436	.99999	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.00465	.99999	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.00495	.99999	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.00524	.99999	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.00553	.99998	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.00582	.99998	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.00611	.99998	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.00640	.99998	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.00669	.99998	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.00698	.99998	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.00727	.99997	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.00756	.99997	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.00785	.99997	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.00814	.99997	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.00844	.99996	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.00873	.99996	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.00902	.99996	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.00931	.99996	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.00960	.99995	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.00989	.99995	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.01018	.99995	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.01047	.99995	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.01076	.99994	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.01105	.99994	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.01134	.99994	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.01164	.99993	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.01193	.99993	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.01222	.99993	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.01251	.99992	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.01280	.99992	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.01309	.99991	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.01338	.99991	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.01367	.99991	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.01396	.99990	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.01425	.99990	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.01454	.99989	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.01483	.99989	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.01513	.99989	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.01542	.99988	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.01571	.99988	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.01600	.99987	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.01629	.99987	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.01658	.99986	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.01687	.99986	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.01716	.99985	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	89°		88°		87°		86°		85°		

′	15°		16°		17°		18°		19°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.25882	.96593	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	60
1	.25910	.96585	.27592	.96118	.29265	.95622	.30929	.95097	.32584	.94542	59
2	.25938	.96578	.27620	.96110	.29293	.95613	.30957	.95088	.32612	.94533	58
3	.25966	.96570	.27648	.96102	.29321	.95605	.30985	.95079	.32639	.94523	57
4	.25994	.96562	.27676	.96094	.29348	.95596	.31012	.95070	.32667	.94514	56
5	.26022	.96555	.27704	.96086	.29376	.95588	.31040	.95061	.32694	.94504	55
6	.26050	.96547	.27731	.96078	.29404	.95579	.31068	.95052	.32722	.94495	54
7	.26079	.96540	.27759	.96070	.29432	.95571	.31095	.95043	.32749	.94485	53
8	.26107	.96532	.27787	.96062	.29460	.95562	.31123	.95033	.32777	.94476	52
9	.26135	.96524	.27815	.96054	.29487	.95554	.31151	.95024	.32804	.94466	51
10	.26163	.96517	.27843	.96046	.29515	.95545	.31178	.95015	.32832	.94457	50
11	.26191	.96509	.27871	.96037	.29543	.95536	.31206	.95006	.32859	.94447	49
12	.26219	.96502	.27899	.96029	.29571	.95528	.31233	.94997	.32887	.94438	48
13	.26247	.96494	.27927	.96021	.29599	.95519	.31261	.94988	.32914	.94428	47
14	.26275	.96486	.27955	.96013	.29626	.95511	.31289	.94979	.32942	.94418	46
15	.26303	.96479	.27983	.96005	.29654	.95502	.31316	.94970	.32969	.94409	45
16	.26331	.96471	.28011	.95997	.29682	.95493	.31344	.94961	.32997	.94399	44
17	.26359	.96463	.28039	.95989	.29710	.95485	.31372	.94952	.33024	.94390	43
18	.26387	.96456	.28067	.95981	.29737	.95476	.31399	.94943	.33051	.94380	42
19	.26415	.96448	.28095	.95972	.29765	.95467	.31427	.94933	.33079	.94370	41
20	.26443	.96440	.28123	.95964	.29793	.95459	.31454	.94924	.33106	.94361	40
21	.26471	.96433	.28150	.95956	.29821	.95450	.31482	.94915	.33134	.94351	39
22	.26500	.96425	.28178	.95948	.29849	.95441	.31510	.94906	.33161	.94342	38
23	.26528	.96417	.28206	.95940	.29876	.95433	.31537	.94897	.33189	.94332	37
24	.26556	.96410	.28234	.95931	.29904	.95424	.31565	.94888	.33216	.94322	36
25	.26584	.96402	.28262	.95923	.29932	.95415	.31593	.94878	.33244	.94313	35
26	.26612	.96394	.28290	.95915	.29960	.95407	.31620	.94869	.33271	.94303	34
27	.26640	.96386	.28318	.95907	.29987	.95398	.31648	.94860	.33298	.94293	33
28	.26668	.96379	.28346	.95898	.30015	.95389	.31675	.94851	.33326	.94284	32
29	.26696	.96371	.28374	.95890	.30043	.95380	.31703	.94842	.33353	.94274	31
30	.26724	.96363	.28402	.95882	.30071	.95372	.31730	.94832	.33381	.94264	30
31	.26752	.96355	.28429	.95874	.30098	.95363	.31758	.94823	.33408	.94254	29
32	.26780	.96347	.28457	.95865	.30126	.95354	.31786	.94814	.33436	.94245	28
33	.26808	.96340	.28485	.95857	.30154	.95345	.31813	.94805	.33463	.94235	27
34	.26836	.96332	.28513	.95849	.30182	.95337	.31841	.94795	.33490	.94225	26
35	.26864	.96324	.28541	.95841	.30209	.95328	.31868	.94786	.33518	.94215	25
36	.26892	.96316	.28569	.95832	.30237	.95319	.31896	.94777	.33545	.94206	24
37	.26920	.96308	.28597	.95824	.30265	.95310	.31923	.94768	.33573	.94196	23
38	.26948	.96301	.28625	.95816	.30292	.95301	.31951	.94758	.33600	.94186	22
39	.26976	.96293	.28652	.95807	.30320	.95293	.31979	.94749	.33627	.94176	21
40	.27004	.96285	.28680	.95799	.30348	.95284	.32006	.94740	.33655	.94167	20
41	.27032	.96277	.28708	.95791	.30376	.95275	.32034	.94730	.33682	.94157	19
42	.27060	.96269	.28736	.95782	.30403	.95266	.32061	.94721	.33710	.94147	18
43	.27088	.96261	.28764	.95774	.30431	.95257	.32089	.94712	.33737	.94137	17
44	.27116	.96253	.28792	.95766	.30459	.95248	.32116	.94702	.33764	.94127	16
45	.27144	.96246	.28820	.95757	.30486	.95240	.32144	.94693	.33792	.94118	15
46	.27172	.96238	.28847	.95749	.30514	.95231	.32171	.94684	.33819	.94108	14
47	.27200	.96230	.28875	.95740	.30542	.95222	.32199	.94674	.33846	.94098	13
48	.27228	.96222	.28903	.95732	.30570	.95213	.32227	.94665	.33874	.94088	12
49	.27256	.96214	.28931	.95724	.30597	.95204	.32254	.94656	.33901	.94078	11
50	.27284	.96206	.28959	.95715	.30625	.95195	.32282	.94646	.33929	.94068	10
51	.27312	.96198	.28987	.95707	.30653	.95186	.32309	.94637	.33956	.94058	9
52	.27340	.96190	.29015	.95698	.30680	.95177	.32337	.94627	.33983	.94049	8
53	.27368	.96182	.29042	.95690	.30708	.95168	.32364	.94618	.34011	.94039	7
54	.27396	.96174	.29070	.95681	.30736	.95159	.32392	.94609	.34038	.94029	6
55	.27424	.96166	.29098	.95673	.30763	.95150	.32419	.94599	.34065	.94019	5
56	.27452	.96158	.29126	.95664	.30791	.95142	.32447	.94590	.34093	.94009	4
57	.27480	.96150	.29154	.95656	.30819	.95133	.32474	.94580	.34120	.93999	3
58	.27508	.96142	.29182	.95647	.30846	.95124	.32502	.94571	.34147	.93989	2
59	.27536	.96134	.29209	.95639	.30874	.95115	.32529	.94561	.34175	.93979	1
60	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	74°		73°		72°		71°		70°		

′	20°		21°		22°		23°		24°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.34202	.93969	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.34229	.93959	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.34257	.93949	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.34284	.93939	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.34311	.93929	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.34339	.93919	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.34366	.93909	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.34393	.93899	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.34421	.93889	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.34448	.93879	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.34475	.93869	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.34503	.93859	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.34530	.93849	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.34557	.93839	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.34584	.93829	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.34612	.93819	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.34639	.93809	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.34666	.93799	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.34694	.93789	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.34721	.93779	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.34748	.93769	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.34775	.93759	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.34803	.93748	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.34830	.93738	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.34857	.93728	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.34884	.93718	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.34912	.93708	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.34939	.93698	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.34966	.93688	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.34993	.93677	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.35021	.93667	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.35048	.93657	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.35075	.93647	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.35102	.93637	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.35130	.93626	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.35157	.93616	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.35184	.93606	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.35211	.93596	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.35239	.93585	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.35266	.93575	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.35293	.93565	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.35320	.93555	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.35347	.93544	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.35375	.93534	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.35402	.93524	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.35429	.93514	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.35456	.93503	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.35484	.93493	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.35511	.93483	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.35538	.93472	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.35565	.93462	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.35592	.93452	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.35619	.93441	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.35647	.93431	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.35674	.93420	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.35701	.93410	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.35728	.93400	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.35755	.93389	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.35782	.93379	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.35810	.93368	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	69°		68°		67°		66°		65°		

′	25°		26°		27°		28°		29°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	60
1	.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	.48506	.87448	59
2	.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	.48532	.87434	58
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	.48557	.87420	57
4	.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	.48583	.87406	56
5	.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	.48608	.87391	55
6	.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	.48634	.87377	54
7	.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	.48659	.87363	53
8	.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	.48684	.87349	52
9	.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	.48710	.87335	51
10	.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	.48735	.87321	50
11	.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	.48761	.87306	49
12	.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	.48786	.87292	48
13	.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	.48811	.87278	47
14	.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	.48837	.87264	46
15	.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	.48862	.87250	45
16	.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	.48888	.87235	44
17	.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	.48913	.87221	43
18	.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	.48938	.87207	42
19	.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	.48964	.87193	41
20	.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	.48989	.87178	40
21	.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	.49014	.87164	39
22	.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	.49040	.87150	38
23	.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	.49065	.87136	37
24	.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	.49090	.87121	36
25	.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	.49116	.87107	35
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	.49141	.87093	34
27	.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	.49166	.87079	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	.49192	.87064	32
29	.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	.49217	.87050	31
30	.43051	.90259	.44620	.89493	.46175	.88701	.47716	.87882	.49242	.87036	30
31	.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	.49268	.87021	29
32	.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	.49293	.87007	28
33	.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	.49318	.86993	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	.49344	.86978	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	.49369	.86964	25
36	.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	.49394	.86949	24
37	.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	.49419	.86935	23
38	.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	.49445	.86921	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	.49470	.86906	21
40	.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	.49495	.86892	20
41	.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	.49521	.86878	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	.49546	.86863	18
43	.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	.49571	.86849	17
44	.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	.49596	.86834	16
45	.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	.49622	.86820	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	.49647	.86805	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	.49672	.86791	13
48	.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	.49697	.86777	12
49	.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	.49723	.86762	11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	.49748	.86748	10
51	.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	.49773	.86733	9
52	.43628	.89981	.45192	.89206	.46742	.88404	.48277	.87575	.49798	.86719	8
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	.49824	.86704	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	.49849	.86690	6
55	.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	.49874	.86675	5
56	.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	.49899	.86661	4
57	.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	.49924	.86646	3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	.49950	.86632	2
59	.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	.49975	.86617	1
60	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	.50000	.86603	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	64°		63°		62°		61°		60°		

′	30°		31°		32°		33°		34°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	60
1	.50025	.86588	.51529	.85702	.53017	.84789	.54488	.83851	.55943	.82887	59
2	.50050	.86573	.51554	.85687	.53041	.84774	.54513	.83835	.55968	.82871	58
3	.50076	.86559	.51579	.85672	.53066	.84759	.54537	.83819	.55992	.82855	57
4	.50101	.86544	.51604	.85657	.53091	.84743	.54561	.83804	.56016	.82839	56
5	.50126	.86530	.51628	.85642	.53115	.84728	.54586	.83788	.56040	.82822	55
6	.50151	.86515	.51653	.85627	.53140	.84712	.54610	.83772	.56064	.82806	54
7	.50176	.86501	.51678	.85612	.53164	.84697	.54635	.83756	.56088	.82790	53
8	.50201	.86486	.51703	.85597	.53189	.84681	.54659	.83740	.56112	.82773	52
9	.50227	.86471	.51728	.85582	.53214	.84666	.54683	.83724	.56136	.82757	51
10	.50252	.86457	.51753	.85567	.53238	.84650	.54708	.83708	.56160	.82741	50
11	.50277	.86442	.51778	.85551	.53263	.84635	.54732	.83692	.56184	.82724	49
12	.50302	.86427	.51803	.85536	.53288	.84619	.54756	.83676	.56208	.82708	48
13	.50327	.86413	.51828	.85521	.53312	.84604	.54781	.83660	.56232	.82692	47
14	.50352	.86398	.51852	.85506	.53337	.84588	.54805	.83645	.56256	.82675	46
15	.50377	.86384	.51877	.85491	.53361	.84573	.54829	.83629	.56280	.82659	45
16	.50403	.86369	.51902	.85476	.53386	.84557	.54854	.83613	.56305	.82643	44
17	.50428	.86354	.51927	.85461	.53411	.84542	.54878	.83597	.56329	.82626	43
18	.50453	.86340	.51952	.85446	.53435	.84526	.54902	.83581	.56353	.82610	42
19	.50478	.86325	.51977	.85431	.53460	.84511	.54927	.83565	.56377	.82593	41
20	.50503	.86310	.52002	.85416	.53484	.84495	.54951	.83549	.56401	.82577	40
21	.50528	.86295	.52026	.85401	.53509	.84480	.54975	.83533	.56425	.82561	39
22	.50553	.86281	.52051	.85385	.53534	.84464	.54999	.83517	.56449	.82544	38
23	.50578	.86266	.52076	.85370	.53558	.84448	.55024	.83501	.56473	.82528	37
24	.50603	.86251	.52101	.85355	.53583	.84433	.55048	.83485	.56497	.82511	36
25	.50628	.86237	.52126	.85340	.53607	.84417	.55072	.83469	.56521	.82495	35
26	.50654	.86222	.52151	.85325	.53632	.84402	.55097	.83453	.56545	.82478	34
27	.50679	.86207	.52175	.85310	.53656	.84386	.55121	.83437	.56569	.82462	33
28	.50704	.86192	.52200	.85294	.53681	.84370	.55145	.83421	.56593	.82446	32
29	.50729	.86178	.52225	.85279	.53705	.84355	.55169	.83405	.56617	.82429	31
30	.50754	.86163	.52250	.85264	.53730	.84339	.55194	.83389	.56641	.82413	30
31	.50779	.86148	.52275	.85249	.53754	.84324	.55218	.83373	.56665	.82396	29
32	.50804	.86133	.52299	.85234	.53779	.84308	.55242	.83356	.56689	.82380	28
33	.50829	.86119	.52324	.85218	.53804	.84292	.55266	.83340	.56713	.82363	27
34	.50854	.86104	.52349	.85203	.53828	.84277	.55291	.83324	.56736	.82347	26
35	.50879	.86089	.52374	.85188	.53853	.84261	.55315	.83308	.56760	.82330	25
36	.50904	.86074	.52399	.85173	.53877	.84245	.55339	.83292	.56784	.82314	24
37	.50929	.86059	.52423	.85157	.53902	.84230	.55363	.83276	.56808	.82297	23
38	.50954	.86045	.52448	.85142	.53926	.84214	.55388	.83260	.56832	.82281	22
39	.50979	.86030	.52473	.85127	.53951	.84198	.55412	.83244	.56856	.82264	21
40	.51004	.86015	.52498	.85112	.53975	.84182	.55436	.83228	.56880	.82248	20
41	.51029	.86000	.52522	.85096	.54000	.84167	.55460	.83212	.56904	.82231	19
42	.51054	.85985	.52547	.85081	.54024	.84151	.55484	.83195	.56928	.82214	18
43	.51079	.85970	.52572	.85066	.54049	.84135	.55509	.83179	.56952	.82198	17
44	.51104	.85956	.52597	.85051	.54073	.84120	.55533	.83163	.56976	.82181	16
45	.51129	.85941	.52621	.85035	.54097	.84104	.55557	.83147	.57000	.82165	15
46	.51154	.85926	.52646	.85020	.54122	.84088	.55581	.83131	.57024	.82148	14
47	.51179	.85911	.52671	.85005	.54146	.84072	.55605	.83115	.57047	.82132	13
48	.51204	.85896	.52696	.84989	.54171	.84057	.55630	.83098	.57071	.82115	12
49	.51229	.85881	.52720	.84974	.54195	.84041	.55654	.83082	.57095	.82098	11
50	.51254	.85866	.52745	.84959	.54220	.84025	.55678	.83066	.57119	.82082	10
51	.51279	.85851	.52770	.84943	.54244	.84009	.55702	.83050	.57143	.82065	9
52	.51304	.85836	.52794	.84928	.54269	.83994	.55726	.83034	.57167	.82048	8
53	.51329	.85821	.52819	.84913	.54293	.83978	.55750	.83017	.57191	.82032	7
54	.51354	.85806	.52844	.84897	.54317	.83962	.55775	.83001	.57215	.82015	6
55	.51379	.85792	.52869	.84882	.54342	.83946	.55799	.82985	.57238	.81999	5
56	.51404	.85777	.52893	.84866	.54366	.83930	.55823	.82969	.57262	.81982	4
57	.51429	.85762	.52918	.84851	.54391	.83915	.55847	.82953	.57286	.81965	3
58	.51454	.85747	.52943	.84836	.54415	.83899	.55871	.82936	.57310	.81949	2
59	.51479	.85732	.52967	.84820	.54440	.83883	.55895	.82920	.57334	.81932	1
60	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	.57358	.81915	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.57358	.81915	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	60
1	.57381	.81899	.58802	.80885	.60205	.79846	.61589	.78783	.62955	.77696	59
2	.57405	.81882	.58826	.80867	.60228	.79829	.61612	.78765	.62977	.77678	58
3	.57429	.81865	.58849	.80850	.60251	.79811	.61635	.78747	.63000	.77660	57
4	.57453	.81848	.58873	.80833	.60274	.79793	.61658	.78729	.63022	.77641	56
5	.57477	.81832	.58896	.80816	.60298	.79776	.61681	.78711	.63045	.77623	55
6	.57501	.81815	.58920	.80799	.60321	.79758	.61704	.78694	.63068	.77605	54
7	.57524	.81798	.58943	.80782	.60344	.79741	.61726	.78676	.63090	.77586	53
8	.57548	.81782	.58967	.80765	.60367	.79723	.61740	.78658	.63113	.77568	52
9	.57572	.81765	.58990	.80748	.60390	.79706	.61772	.78640	.63135	.77550	51
10	.57596	.81748	.59014	.80730	.60414	.79688	.61795	.78622	.63158	.77531	50
11	.57619	.81731	.59037	.80713	.60437	.79671	.61818	.78604	.63180	.77513	49
12	.57643	.81714	.59061	.80696	.60460	.79653	.61841	.78586	.63203	.77494	48
13	.57667	.81698	.59084	.80679	.60483	.79635	.61864	.78568	.63225	.77476	47
14	.57691	.81681	.59108	.80662	.60506	.79618	.61887	.78550	.63248	.77458	46
15	.57715	.81664	.59131	.80644	.60529	.79600	.61909	.78532	.63271	.77439	45
16	.57738	.81647	.59154	.80627	.60553	.79583	.61932	.78514	.63293	.77421	44
17	.57762	.81631	.59178	.80610	.60576	.79565	.61955	.78496	.63316	.77402	43
18	.57786	.81614	.59201	.80593	.60599	.79547	.61978	.78478	.63338	.77384	42
19	.57810	.81597	.59225	.80576	.60622	.79530	.62001	.78460	.63361	.77366	41
20	.57833	.81580	.59248	.80558	.60645	.79512	.62024	.78442	.63383	.77347	40
21	.57857	.81563	.59272	.80541	.60668	.79494	.62046	.78424	.63406	.77329	39
22	.57881	.81546	.59295	.80524	.60691	.79477	.62069	.78405	.63428	.77310	38
23	.57904	.81530	.59318	.80507	.60714	.79459	.62092	.78387	.63451	.77292	37
24	.57928	.81513	.59342	.80489	.60738	.79441	.62115	.78369	.63473	.77273	36
25	.57952	.81496	.59365	.80472	.60761	.79424	.62138	.78351	.63496	.77255	35
26	.57976	.81479	.59389	.80455	.60784	.79406	.62160	.78333	.63518	.77236	34
27	.57999	.81462	.59412	.80438	.60807	.79388	.62183	.78315	.63540	.77218	33
28	.58023	.81445	.59436	.80420	.60830	.79371	.62206	.78297	.63563	.77199	32
29	.58047	.81428	.59459	.80403	.60853	.79353	.62229	.78279	.63585	.77181	31
30	.58070	.81412	.59482	.80386	.60876	.79335	.62251	.78261	.63608	.77162	30
31	.58094	.81395	.59506	.80368	.60899	.79318	.62274	.78243	.63630	.77144	29
32	.58118	.81378	.59529	.80351	.60922	.79300	.62297	.78225	.63653	.77125	28
33	.58141	.81361	.59552	.80334	.60945	.79282	.62320	.78206	.63675	.77107	27
34	.58165	.81344	.59576	.80316	.60968	.79264	.62342	.78188	.63698	.77088	26
35	.58189	.81327	.59599	.80299	.60991	.79247	.62365	.78170	.63720	.77070	25
36	.58212	.81310	.59622	.80282	.61015	.79229	.62388	.78152	.63742	.77051	24
37	.58236	.81293	.59646	.80264	.61038	.79211	.62411	.78134	.63765	.77033	23
38	.58260	.81276	.59669	.80247	.61061	.79193	.62433	.78116	.63787	.77014	22
39	.58283	.81259	.59693	.80230	.61084	.79176	.62456	.78098	.63810	.76996	21
40	.58307	.81242	.59716	.80212	.61107	.79158	.62479	.78079	.63832	.76977	20
41	.58330	.81225	.59739	.80195	.61130	.79140	.62502	.78061	.63854	.76959	19
42	.58354	.81208	.59763	.80178	.61153	.79122	.62524	.78043	.63877	.76940	18
43	.58378	.81191	.59786	.80160	.61176	.79105	.62547	.78025	.63899	.76921	17
44	.58401	.81174	.59809	.80143	.61199	.79087	.62570	.78007	.63922	.76903	16
45	.58425	.81157	.59832	.80125	.61222	.79069	.62592	.77988	.63944	.76884	15
46	.58449	.81140	.59856	.80108	.61245	.79051	.62615	.77970	.63966	.76866	14
47	.58472	.81123	.59879	.80091	.61268	.79033	.62638	.77952	.63989	.76847	13
48	.58496	.81106	.59902	.80073	.61291	.79016	.62660	.77934	.64011	.76828	12
49	.58519	.81089	.59926	.80056	.61314	.78998	.62683	.77916	.64033	.76810	11
50	.58543	.81072	.59949	.80038	.61337	.78980	.62706	.77897	.64056	.76791	10
51	.58567	.81055	.59972	.80021	.61360	.78962	.62728	.77879	.64078	.76772	9
52	.58590	.81038	.59995	.80003	.61383	.78944	.62751	.77861	.64100	.76754	8
53	.58614	.81021	.60019	.79986	.61406	.78926	.62774	.77843	.64123	.76735	7
54	.58637	.81004	.60042	.79968	.61429	.78908	.62796	.77824	.64145	.76717	6
55	.58661	.80987	.60065	.79951	.61451	.78891	.62819	.77806	.64167	.76698	5
56	.58684	.80970	.60089	.79934	.61474	.78873	.62842	.77788	.64190	.76679	4
57	.58708	.80953	.60112	.79916	.61497	.78855	.62864	.77769	.64212	.76661	3
58	.58731	.80936	.60135	.79899	.61520	.78837	.62887	.77751	.64234	.76642	2
59	.58755	.80919	.60158	.79881	.61543	.78819	.62909	.77733	.64256	.76623	1
60	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.64279	.76604	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
1	.64301	.76586	.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
2	.64323	.76567	.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
3	.64346	.76548	.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
4	.64368	.76530	.65694	.75395	.66999	.74237	.68285	.73056	.69549	.71853	56
5	.64390	.76511	.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
6	.64412	.76492	.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
7	.64435	.76473	.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
8	.64457	.76455	.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
9	.64479	.76436	.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
10	.64501	.76417	.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
11	.64524	.76398	.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
12	.64546	.76380	.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
13	.64568	.76361	.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
14	.64590	.76342	.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
15	.64612	.76323	.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
16	.64635	.76304	.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
17	.64657	.76286	.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
18	.64679	.76267	.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
19	.64701	.76248	.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
20	.64723	.76229	.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
21	.64746	.76210	.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
22	.64768	.76192	.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
23	.64790	.76173	.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
24	.64812	.76154	.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
25	.64834	.76135	.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
26	.64856	.76116	.66175	.74973	.67473	.73806	.68751	.72617	.70008	.71407	34
27	.64878	.76097	.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
28	.64901	.76078	.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
29	.64923	.76059	.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
30	.64945	.76041	.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
31	.64967	.76022	.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
32	.64989	.76003	.66306	.74857	.67602	.73688	.68878	.72497	.70132	.71284	28
33	.65011	.75984	.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
34	.65033	.75965	.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
35	.65055	.75946	.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
36	.65077	.75927	.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
37	.65100	.75908	.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
38	.65122	.75889	.66436	.74741	.67730	.73570	.69004	.72377	.70257	.71162	22
39	.65144	.75870	.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
40	.65166	.75851	.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
41	.65188	.75832	.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
42	.65210	.75813	.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
43	.65232	.75794	.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
44	.65254	.75775	.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
45	.65276	.75756	.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
46	.65298	.75738	.66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
47	.65320	.75719	.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
48	.65342	.75700	.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
49	.65364	.75680	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
50	.65386	.75661	.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
51	.65408	.75642	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.65430	.75623	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.65452	.75604	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.65474	.75585	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.65496	.75566	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.65518	.75547	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
57	.65540	.75528	.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
58	.65562	.75509	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.65584	.75490	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	49°		48°		47°		46°		45°		

′	0°		1°		2°		3°		4°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.00000	Infin.	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	60
1	.00029	3437.75	.01775	56.3506	.03521	28.3994	.05270	18.9755	.07022	14.2411	59
2	.00058	1718.87	.01804	55.4415	.03550	28.1664	.05299	18.8711	.07051	14.1821	58
3	.00087	1145.92	.01833	54.5613	.03579	27.9372	.05328	18.7678	.07080	14.1235	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	.07110	14.0655	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	.07139	14.0079	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	.07168	13.9507	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	.07197	13.8940	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	.07227	13.8378	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	.07256	13.7821	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	.07285	13.7267	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	.07314	13.6719	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	.07344	13.6174	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	.07373	13.5634	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	.07402	13.5098	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	.07431	13.4566	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	.07461	13.4039	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	.07490	13.3515	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	.07519	13.2996	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	.07548	13.2480	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	.07578	13.1969	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	.07607	13.1461	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	.07636	13.0958	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	.07665	13.0458	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	.07695	12.9962	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	.07724	12.9469	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	.07753	12.8981	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	.07782	12.8496	33
28	.00815	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	.07812	12.8014	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	.07841	12.7536	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	.07870	12.7062	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	.07899	12.6591	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	.07929	12.6124	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	.07958	12.5660	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	.07987	12.5199	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	.08017	12.4742	25
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	.08046	12.4288	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	.08075	12.3838	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	.08104	12.3390	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	.08134	12.2946	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	.08163	12.2505	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	.08192	12.2067	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	.08221	12.1632	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	.08251	12.1201	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9463	.06525	15.3254	.08280	12.0772	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	.08309	12.0346	15
46	.01338	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1893	.08339	11.9923	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	.08368	11.9504	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	.08397	11.9087	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	.08427	11.8673	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	.08456	11.8262	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	.08485	11.7853	9
52	.01513	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	.08514	11.7448	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	.08544	11.7045	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	.08573	11.6645	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	.08602	11.6248	5
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	.08632	11.5853	4
57	.01658	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	.08661	11.5461	3
58	.01687	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	.08690	11.5072	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	.08720	11.4685	1
60	.01746	57.2900	.03402	28.6363	.05241	19.0811	.06993	14.3007	.08749	11.4301	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	89°		88°		87°		86°		85°		

′	5°		6°		7°		8°		9°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	60
1	.08778	11.3919	.10540	9.48781	.12308	8.12481	.14084	7.10038	.15868	6.30189	59
2	.08807	11.3540	.10569	9.46141	.12338	8.10536	.14113	7.08546	.15898	6.29007	58
3	.08837	11.3163	.10599	9.43515	.12367	8.08600	.14143	7.07059	.15928	6.27829	57
4	.08866	11.2789	.10628	9.40904	.12397	8.06674	.14173	7.05579	.15958	6.26655	56
5	.08895	11.2417	.10657	9.38307	.12426	8.04756	.14202	7.04105	.15988	6.25486	55
6	.08925	11.2048	.10687	9.35724	.12456	8.02848	.14232	7.02637	.16017	6.24321	54
7	.08954	11.1681	.10716	9.33155	.12485	8.00948	.14262	7.01174	.16047	6.23160	53
8	.08983	11.1316	.10746	9.30599	.12515	7.99058	.14291	6.99718	.16077	6.22003	52
9	.09013	11.0954	.10775	9.28058	.12544	7.97176	.14321	6.98268	.16107	6.20851	51
10	.09042	11.0594	.10805	9.25530	.12574	7.95302	.14351	6.96823	.16137	6.19703	50
11	.09071	11.0237	.10834	9.23016	.12603	7.93438	.14381	6.95385	.16167	6.18559	49
12	.09101	10.9882	.10863	9.20516	.12633	7.91582	.14410	6.93952	.16196	6.17419	48
13	.09130	10.9529	.10893	9.18028	.12662	7.89734	.14440	6.92525	.16226	6.16283	47
14	.09159	10.9178	.10922	9.15554	.12692	7.87895	.14470	6.91104	.16256	6.15151	46
15	.09189	10.8829	.10952	9.13093	.12722	7.86064	.14499	6.89688	.16286	6.14023	45
16	.09218	10.8483	.10981	9.10646	.12751	7.84242	.14529	6.88278	.16316	6.12899	44
17	.09247	10.8139	.11011	9.08211	.12781	7.82428	.14559	6.86874	.16346	6.11779	43
18	.09277	10.7797	.11040	9.05789	.12810	7.80622	.14588	6.85475	.16376	6.10664	42
19	.09306	10.7457	.11070	9.03379	.12840	7.78825	.14618	6.84082	.16405	6.09552	41
20	.09335	10.7119	.11099	9.00983	.12869	7.77035	.14648	6.82694	.16435	6.08444	40
21	.09365	10.6783	.11128	8.98598	.12899	7.75254	.14678	6.81812	.16465	6.07340	39
22	.09394	10.6450	.11158	8.96227	.12929	7.73480	.14707	6.79936	.16495	6.06240	38
23	.09423	10.6118	.11187	8.93867	.12958	7.71715	.14737	6.78564	.16525	6.05143	37
24	.09453	10.5789	.11217	8.91520	.12988	7.69957	.14767	6.77199	.16555	6.04051	36
25	.09482	10.5462	.11246	8.89185	.13017	7.68208	.14796	6.75838	.16585	6.02962	35
26	.09511	10.5136	.11276	8.86862	.13047	7.66466	.14826	6.74483	.16615	6.01878	34
27	.09541	10.4813	.11305	8.84551	.13076	7.64732	.14856	6.73133	.16645	6.00797	33
28	.09570	10.4491	.11335	8.82252	.13106	7.63005	.14886	6.71789	.16674	5.99720	32
29	.09600	10.4172	.11364	8.79964	.13136	7.61287	.14915	6.70450	.16704	5.98646	31
30	.09629	10.3854	.11394	8.77689	.13165	7.59575	.14945	6.69116	.16734	5.97576	30
31	.09658	10.3538	.11423	8.75425	.13195	7.57872	.14975	6.67787	.16764	5.96510	29
32	.09688	10.3224	.11452	8.73172	.13224	7.56176	.15005	6.66463	.16794	5.95448	28
33	.09717	10.2913	.11482	8.70931	.13254	7.54487	.15034	6.65144	.16824	5.94390	27
34	.09746	10.2602	.11511	8.68701	.13284	7.52806	.15064	6.63831	.16854	5.93335	26
35	.09776	10.2294	.11541	8.66482	.13313	7.51132	.15094	6.62523	.16884	5.92283	25
36	.09805	10.1988	.11570	8.64275	.13343	7.49465	.15124	6.61219	.16914	5.91236	24
37	.09834	10.1683	.11600	8.62078	.13372	7.47806	.15153	6.59921	.16944	5 90191	23
38	.09864	10.1381	.11629	8.59893	.13402	7.46154	.15183	6.58627	.16974	5.89151	22
39	.09893	10.1080	.11659	8.57718	.13432	7.44509	.15213	6.57339	.17004	5.88114	21
40	.09923	10.0780	.11688	8.55555	.13461	7.42871	.15243	6.56055	.17033	5.87080	20
41	.09952	10.0483	.11718	8.53402	.13491	7.41240	.15272	6.54777	.17063	5.86051	19
42	.09981	10.0187	.11747	8.51259	.13521	7.39616	.15302	6.53503	.17093	5.85024	18
43	.10011	9.98931	.11777	8.49128	.13550	7.37999	.15332	6.52234	.17123	5.84001	17
44	.10040	9.96007	.11806	8.47007	.13580	7.36389	.15362	6.50970	.17153	5.82982	16
45	.10069	9.93101	.11836	8.44896	.13609	7.34786	.15391	6.49710	.17183	5.81966	15
46	.10099	9.90211	.11865	8.42795	.13639	7.33190	.15421	6.48456	.17213	5.80953	14
47	.10128	9.87338	.11895	8.40705	.13669	7.31600	.15451	6.47206	.17243	5.79944	13
48	.10158	9.84482	.11924	8.38625	.13698	7.30018	.15481	6.45961	.17273	5.78938	12
49	.10187	9.81641	.11954	8.36555	.13728	7.28442	.15511	6.44720	.17303	5.77936	11
50	.10216	9.78817	.11983	8.34496	.13758	7.26873	.15540	6.43484	.17333	5.76937	10
51	.10246	9.76009	.12013	8.32446	.13787	7.25310	.15570	6.42253	.17363	5.75941	9
52	.10275	9.73217	.12042	8.30406	.13817	7.23754	.15600	6.41026	.17393	5.74949	8
53	.10305	9.70441	.12072	8.28376	.13846	7.22204	.15630	6.39804	.17423	5.73960	7
54	.10334	9.67680	.12101	8.26355	.13876	7.20661	.15660	6.38587	.17453	5.72974	6
55	.10363	9.64935	.12131	8.24345	.13906	7.19125	.15689	6.37374	.17483	5.71992	5
56	.10393	9.62205	.12160	8.22344	.13935	7.17594	.15719	6.36165	.17513	5.71013	4
57	.10422	9.59490	.12190	8.20352	.13965	7.16071	.15749	6.34961	.17543	5.70037	3
58	.10452	9.56791	.12219	8.18370	.13995	7.14553	.15779	6.33761	.17573	5.69064	2
59	.10481	9.54106	.12249	8.16398	.14024	7.13042	.15809	6.32566	.17603	5.68094	1
60	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	.17633	5.67128	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	84°		83°		82°		81°		80°		

′	10°		11°		12°		13°		14°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.17633	5.67128	.19438	5.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	60
1	.17663	5.66165	.19468	5.13658	.21286	4.69791	.23117	4.32573	.24964	4.00582	59
2	.17693	5.65205	.19498	5.12862	.21316	4.69121	.23148	4.32001	.24995	4.00086	58
3	.17723	5.64248	.19529	5.12069	.21347	4.68452	.23179	4.31430	.25026	3.99592	57
4	.17753	5.63295	.19559	5.11279	.21377	4.67786	.23209	4.30860	.25056	3.99099	56
5	.17783	5.62344	.19589	5.10490	.21408	4.67121	.23240	4.30291	.25087	3.98607	55
6	.17813	5.61397	.19619	5.09704	.21438	4.66458	.23271	4.29724	.25118	3.98117	54
7	.17843	5.60452	.19649	5.08921	.21469	4.65797	.23301	4.29159	.25149	3.97627	53
8	.17873	5.59511	.19680	5.08139	.21499	4.65138	.23332	4.28595	.25180	3.97139	52
9	.17903	5.58573	.19710	5.07360	.21529	4.64480	.23363	4.28032	.25211	3.96651	51
10	.17933	5.57638	.19740	5.06584	.21560	4.63825	.23393	4.27471	.25242	3.96165	50
11	.17963	5.56706	.19770	5.05809	.21590	4.63171	.23424	4.26911	.25273	3.95680	49
12	.17993	5.55777	.19801	5.05037	.21621	4.62518	.23455	4.26352	.25304	3.95196	48
13	.18023	5.54851	.19831	5.04267	.21651	4.61868	.23485	4.25795	.25335	3.94713	47
14	.18053	5.53927	.19861	5.03499	.21682	4.61219	.23516	4.25239	.25366	3.94232	46
15	.18083	5.53007	.19891	5.02734	.21712	4.60572	.23547	4.24685	.25397	3.93751	45
16	.18113	5.52090	.19921	5.01971	.21743	4.59927	.23578	4.24132	.25428	3.93271	44
17	.18143	5.51176	.19952	5.01210	.21773	4.59283	.23608	4.23580	.25459	3.92793	43
18	.18173	5.50264	.19982	5.00451	.21804	4.58641	.23639	4.23030	.25490	3.92316	42
19	.18203	5.49356	.20012	4.99695	.21834	4.58001	.23670	4.22481	.25521	3.91839	41
20	.18233	5.48451	.20042	4.98940	.21864	4.57363	.23700	4.21933	.25552	3.91364	40
21	.18263	5.47548	.20073	4.98188	.21895	4.56726	.23731	4.21387	.25583	3.90890	39
22	.18293	5.46648	.20103	4.97438	.21925	4.56091	.23762	4.20842	.25614	3.90417	38
23	.18323	5.45751	.20133	4.96690	.21956	4.55458	.23793	4.20298	.25645	3.89945	37
24	.18353	5.44857	.20164	4.95945	.21986	4.54826	.23823	4.19756	.25676	3.89474	36
25	.18384	5.43966	.20194	4.95201	.22017	4.54196	.23854	4.19215	.25707	3.89004	35
26	.18414	5.43077	.20224	4.94460	.22047	4.53568	.23885	4.18675	.25738	3.88536	34
27	.18444	5.42192	.20254	4.93721	.22078	4.52941	.23916	4.18137	.25769	3.88068	33
28	.18474	5.41309	.20285	4.92984	.22108	4.52316	.23946	4.17600	.25800	3.87601	32
29	.18504	5.40429	.20315	4.92249	.22139	4.51693	.23977	4.17064	.25831	3.87136	31
30	.18534	5.39552	.20345	4.91516	.22169	4.51071	.24008	4.16530	.25862	3.86671	30
31	.18564	5.38677	.20376	4.90785	.22200	4.50451	.24039	4.15997	.25893	3.86208	29
32	.18594	5.37805	.20406	4.90056	.22231	4.49832	.24069	4.15465	.25924	3.85745	28
33	.18624	5.36936	.20436	4.89330	.22261	4.49215	.24100	4.14934	.25955	3.85284	27
34	.18654	5.36070	.20466	4.88605	.22292	4.48600	.24131	4.14405	.25986	3.84824	26
35	.18684	5.35206	.20497	4.87882	.22322	4.47986	.24162	4.13877	.26017	3.84364	25
36	.18714	5.34345	.20527	4.87162	.22353	4.47374	.24193	4.13350	.26048	3.83906	24
37	.18745	5.33487	.20557	4.86444	.22383	4.46764	.24223	4.12825	.26079	3.83449	23
38	.18775	5.32631	.20588	4.85727	.22414	4.46155	.24254	4.12301	.26110	3.82992	22
39	.18805	5.31778	.20618	4.85013	.22444	4.45548	.24285	4.11778	.26141	3.82537	21
40	.18835	5.30928	.20648	4.84300	.22475	4.44942	.24316	4.11256	.26172	3.82083	20
41	.18865	5.30080	.20679	4.83590	.22505	4.44338	.24347	4.10736	.26203	3.81630	19
42	.18895	5.29235	.20709	4.82882	.22536	4.43735	.24377	4.10216	.26235	3.81177	18
43	.18925	5.28393	.20739	4.82175	.22567	4.43134	.24408	4.09699	.26266	3.80726	17
44	.18955	5.27553	.20770	4.81471	.22597	4.42534	.24439	4.09182	.26297	3.80276	16
45	.18986	5.26715	.20800	4.80769	.22628	4.41936	.24470	4.08666	.26328	3.79827	15
46	.19016	5.25880	.20830	4.80068	.22658	4.41340	.24501	4.08152	.26359	3.79378	14
47	.19046	5.25048	.20861	4.79370	.22689	4.40745	.24532	4.07639	.26390	3.78931	13
48	.19076	5.24218	.20891	4.78673	.22719	4.40152	.24562	4.07127	.26421	3.78485	12
49	.19106	5.23391	.20921	4.77978	.22750	4.39560	.24593	4.06616	.26452	3.78040	11
50	.19136	5.22566	.20952	4.77286	.22781	4.38969	.24624	4.06107	.26483	3.77595	10
51	.19166	5.21744	.20982	4.76595	.22811	4.38381	.24655	4.05599	.26515	3.77152	9
52	.19197	5.20925	.21013	4.75906	.22842	4.37793	.24686	4.05092	.26546	3.76709	8
53	.19227	5.20107	.21043	4.75219	.22872	4.37207	.24717	4.04586	.26577	3.76268	7
	.19257	5.19293	.21073	4.74534	.22903	4.36623	.24747	4.04081	.26608	3.75828	6
	[illegible]87	5.18480	.21104	4.73851	.22934	4.36040	.24778	4.03578	.26639	3.75388	5
	7	5.17671	.21134	4.73170	.22964	4.35459	.24809	4.03076	.26670	3.74950	4
		5.16863	.21164	4.72490	.22995	4.34879	.24840	4.02574	.26701	3.74512	3
		5.16058	.21195	4.71813	.23026	4.34300	.24871	4.02074	.26733	3.74075	2
		.15256	.21225	4.71137	.23056	4.33723	.24902	4.01576	.26764	3.73640	1
		.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	0
		Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	79°		78°		77°		76°		75°		

′	15°		16°		17°		18°		19°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.26795	3.73205	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	60
1	.26826	3.72771	.28706	3.48359	.30605	3.26745	.32524	3.07464	.34465	2.90147	59
2	.26857	3.72338	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
3	.26888	3.71907	.28769	3.47596	.30669	3.26067	.32588	3.06857	.34530	2.89600	57
4	.26920	3.71476	.28800	3.47216	.30700	3.25729	.32621	3.06554	.34563	2.89327	56
5	.26951	3.71046	.28832	3.46837	.30732	3.25392	.32653	3.06252	.34596	2.89055	55
6	.26982	3.70616	.28864	3.46458	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.27013	3.70188	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.27044	3.69761	.28927	3.45703	.30828	3.24383	.32749	3.05349	.34693	2.88240	52
9	.27076	3.69335	.28958	3.45327	.30860	3.24049	.32782	3.05049	.34726	2.87970	51
10	.27107	3.68909	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.27138	3.68485	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.27169	3.68061	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.27201	3.67638	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.27232	3.67217	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.27263	3.66796	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.27294	3.66376	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.27326	3.65957	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.27357	3.65538	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35020	2.85555	42
19	.27388	3.65121	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.27419	3.64705	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.27451	3.64289	.29337	3.40869	.31242	3.20079	.33169	3.01489	.35118	2.84758	39
22	.27482	3.63874	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.27513	3.63461	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.27545	3.63048	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.27576	3.62636	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.27607	3.62224	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.27638	3.61814	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.27670	3.61405	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.27701	3.60996	.29590	3.37955	.31498	3.17481	.33427	2.99158	.35379	2.82653	31
30	.27732	3.60588	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82391	30
31	.27764	3.60181	.29653	3.37234	.31562	3.16838	.33492	2.98580	.35445	2.82130	29
32	.27795	3.59775	.29685	3.36875	.31594	3.16517	.33524	2.98292	.35477	2.81870	28
33	.27826	3.59370	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.27858	3.58966	.29748	3.36158	.31658	3.15877	.33589	2.97717	.35543	2.81350	26
35	.27889	3.58562	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.27921	3.58160	.29811	3.35443	.31722	3.15240	.33654	2.97144	.35608	2.80833	24
37	.27952	3.57758	.29843	3.35087	.31754	3.14922	.33686	2.96858	.35641	2.80574	23
38	.27983	3.57357	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.28015	3.56957	.29906	3.34377	.31818	3.14288	.33751	2.96288	.35707	2.80059	21
40	.28046	3.56557	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.28077	3.56159	.29970	3.33670	.31882	3.13656	.33816	2.95721	.35772	2.79545	19
42	.28109	3.55761	.30001	3.33317	.31914	3.13341	.33848	2.95437	.35805	2.79289	18
43	.28140	3.55364	.30033	3.32965	.31946	3.13027	.33881	2.95155	.35838	2.79033	17
44	.28172	3.54968	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.28203	3.54573	.30097	3.32264	.32010	3.12400	.33945	2.94591	.35904	2.78523	15
46	.28234	3.54179	.30128	3.31914	.32042	3.12087	.33978	2.94309	.35937	2.78269	14
47	.28266	3.53785	.30160	3.31565	.32074	3.11775	.34010	2.94028	.35969	2.78014	13
48	.28297	3.53393	.30192	3.31216	.32106	3.11464	.34043	2.93748	.36002	2.77761	12
49	.28329	3.53001	.30224	3.30868	.32139	3.11153	.34075	2.93468	.36035	2.77507	11
50	.28360	3.52609	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.28391	3.52219	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.28423	3.51829	.30319	3.29829	.32235	3.10223	.34173	2.92632	.36134	2.76750	8
53	.28454	3.51441	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76498	7
54	.28486	3.51053	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.28517	3.50666	.30414	3.28795	.32331	3.09298	.34270	2.91799	.36232	2.75996	5
56	.28549	3.50279	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.28580	3.49894	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.28612	3.49509	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.28643	3.49125	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	74°		73°		72°		71°		70°		

′	20°		21°		22°		23°		24°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	60
1	.36430	2.74499	.38420	2.60283	.40436	2.47302	.42482	2.35395	.44558	2.24428	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42516	2.35205	.44593	2.24252	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42551	2.35015	.44627	2.24077	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42585	2.34825	.44662	2.23902	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	.44697	2.23727	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42654	2.34447	.44732	2.23553	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.34258	.44767	2.23378	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	.44802	2.23204	52
9	.36694	2.72526	.38687	2.58484	.40707	2.45655	.42757	2.33881	.44837	2.23030	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	.44872	2.22857	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	.44907	2.22683	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	.44942	2.22510	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	.44977	2.22337	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	.45012	2.22164	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	.45047	2.21992	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32570	.45082	2.21819	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	.45117	2.21647	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	.45152	2.21475	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	.45187	2.21304	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	.45222	2.21132	40
21	.37090	2.69612	.39089	2.55827	.41115	2.43220	.43170	2.31641	.45257	2.20961	39
22	.37123	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	.45292	2.20790	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43230	2.31271	.45327	2.20619	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	.45362	2.20449	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	.45397	2.20278	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	.45432	2.20108	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	.45467	2.19938	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	.45502	2.19769	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	.45538	2.19599	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	.45573	2.19430	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	.45608	2.19261	29
32	.37455	2.66989	.39458	2.53432	.41490	2.41025	.43550	2.29619	.45643	2.19092	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	.45678	2.18923	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	.45713	2.18755	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	.45748	2.18587	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	.45784	2.18419	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	.45819	2.18251	23
38	.37654	2.65576	.39660	2.52142	.41694	2.39841	.43758	2.28528	.45854	2.18084	22
39	.37687	2.65342	.39694	2.51929	.41728	2.37645	.43793	2.28348	.45889	2.17916	21
40	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	.45924	2.17749	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	.45960	2.17582	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	.45995	2.17416	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38863	.43932	2.27626	.46030	2.17249	17
44	.37853	2.64177	.39862	2.50864	.41899	2.38668	.43966	2.27447	.46065	2.17083	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	.46101	2.16917	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	.46136	2.16751	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	.46171	2.16585	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	.46206	2.16420	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	.46242	2.16255	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2.26374	.46277	2.16090	10
51	.38086	2.62561	.40098	2.49386	.42139	2.37311	.44210	2.26196	.46312	2.15925	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	.46348	2.15760	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	.46383	2.15596	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	.46418	2.15432	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	.46454	2.15268	5
56	.38253	2.61418	.40267	2.48340	.42310	2.36349	.44384	2.25309	.46489	2.15104	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	.46525	2.14940	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	.46560	2.14777	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	.46595	2.14614	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	.46631	2.14451	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	69°		68°		67°		66°		65°		

′	25°		26°		27°		28°		29°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.46631	2.14451	.48773	2.05030	.50953	1.96261	.53171	1.88073	.55431	1.80405	60
1	.46666	2.14288	.48809	2.04879	.50989	1.96120	.53208	1.87941	.55469	1.80281	59
2	.46702	2.14125	.48845	2.04728	.51026	1.95979	.53246	1.87809	.55507	1.80158	58
3	.46737	2.13963	.48881	2.04577	.51063	1.95838	.53283	1.87677	.55545	1.80034	57
4	.46772	2.13801	.48917	2.04426	.51099	1.95698	.53320	1.87546	.55583	1.79911	56
5	.46808	2.13639	.48953	2.04276	.51136	1.95557	.53358	1.87415	.55621	1.79788	55
6	.46843	2.13477	.48989	2.04125	.51173	1.95417	.53395	1.87283	.55659	1.79665	54
7	.46879	2.13316	.49026	2.03975	.51209	1.95277	.53432	1.87152	.55697	1.79542	53
8	.46914	2.13154	.49062	2.03825	.51246	1.95137	.53470	1.87021	.55736	1.79419	52
9	.46950	2.12993	.49098	2.03675	.51283	1.94997	.53507	1.86891	.55774	1.79296	51
10	.46985	2.12832	.49134	2.03526	.51319	1.94858	.53545	1.86760	.55812	1.79174	50
11	.47021	2.12671	.49170	2.03376	.51356	1.94718	.53582	1.86630	.55850	1.79051	49
12	.47056	2.12511	.49206	2.03227	.51393	1.94579	.53620	1.86499	.55888	1.78929	48
13	.47092	2.12350	.49242	2.03078	.51430	1.94440	.53657	1.86369	.55926	1.78807	47
14	.47128	2.12190	.49278	2.02929	.51467	1.94301	.53694	1.86239	.55964	1.78685	46
15	.47163	2.12030	.49315	2.02780	.51503	1.94162	.53732	1.86109	.56003	1.78563	45
16	.47199	2.11871	.49351	2.02631	.51540	1.94023	.53769	1.85979	.56041	1.78441	44
17	.47234	2.11711	.49387	2.02483	.51577	1.93885	.53807	1.85850	.56079	1.78319	43
18	.47270	2.11552	.49423	2.02335	.51614	1.93746	.53844	1.85720	.56117	1.78198	42
19	.47305	2.11392	.49459	2.02187	.51651	1.93608	.53882	1.85591	.56156	1.78077	41
20	.47341	2.11233	.49495	2.02039	.51688	1.93470	.53920	1.85462	.56194	1.77955	40
21	.47377	2.11075	.49532	2.01891	.51724	1.93332	.53957	1.85333	.56232	1.77834	39
22	.47412	2.10916	.49568	2.01743	.51761	1.93195	.53995	1.85204	.56270	1.77713	38
23	.47448	2.10758	.49604	2.01596	.51798	1.93057	.54032	1.85075	.56309	1.77592	37
24	.47483	2.10600	.49640	2.01449	.51835	1.92920	.54070	1.84946	.56347	1.77471	36
25	.47519	2.10442	.49677	2.01302	.51872	1.92782	.54107	1.84818	.56385	1.77351	35
26	.47555	2.10284	.49713	2.01155	.51909	1.92645	.54145	1.84689	.56424	1.77230	34
27	.47590	2.10126	.49749	2.01008	.51946	1.92508	.54183	1.84561	.56462	1.77110	33
28	.47626	2.09969	.49786	2.00862	.51983	1.92371	.54220	1.84433	.56501	1.76990	32
29	.47662	2.09811	.49822	2.00715	.52020	1.92235	.54258	1.84305	.56539	1.76869	31
30	.47698	2.09654	.49858	2.00569	.52057	1.92098	.54296	1.84177	.56577	1.76749	30
31	.47733	2.09498	.49894	2.00423	.52094	1.91962	.54333	1.84049	.56616	1.76629	29
32	.47769	2.09341	.49931	2.00277	.52131	1.91826	.54371	1.83922	.56654	1.76510	28
33	.47805	2.09184	.49967	2.00131	.52168	1.91690	.54409	1.83794	.56693	1.76390	27
34	.47840	2.09028	.50004	1.99986	.52205	1.91554	.54446	1.83667	.56731	1.76271	26
35	.47876	2.08872	.50040	1.99841	.52242	1.91418	.54484	1.83540	.56769	1.76151	25
36	.47912	2.08716	.50076	1.99695	.52279	1.91282	.54522	1.83413	.56808	1.76032	24
37	.47948	2.08560	.50113	1.99550	.52316	1.91147	.54560	1.83286	.56846	1.75913	23
38	.47984	2.08405	.50149	1.99406	.52353	1.91012	.54597	1.83159	.56885	1.75794	22
39	.48019	2.08250	.50185	1.99261	.52390	1.90876	.54635	1.83033	.56923	1.75675	21
40	.48055	2.08094	.50222	1.99116	.52427	1.90741	.54673	1.82906	.56962	1.75556	20
41	.48091	2.07939	.50258	1.98972	.52464	1.90607	.54711	1.82780	.57000	1.75437	19
42	.48127	2.07785	.50295	1.98828	.52501	1.90472	.54748	1.82654	.57039	1.75319	18
43	.48163	2.07630	.50331	1.98684	.52538	1.90337	.54786	1.82528	.57078	1.75200	17
44	.48198	2.07476	.50368	1.98540	.52575	1.90203	.54824	1.82402	.57116	1.75082	16
45	.48234	2.07321	.50404	1.98396	.52613	1.90069	.54862	1.82276	.57155	1.74964	15
46	.48270	2.07167	.50441	1.98253	.52650	1.89935	.54900	1.82150	.57193	1.74846	14
47	.48306	2.07014	.50477	1.98110	.52687	1.89801	.54938	1.82025	.57232	1.74728	13
48	.48342	2.06860	.50514	1.97966	.52724	1.89667	.54975	1.81899	.57271	1.74610	12
49	.48378	2.06706	.50550	1.97823	.52761	1.89533	.55013	1.81774	.57309	1.74492	11
50	.48414	2.06553	.50587	1.97681	.52798	1.89400	.55051	1.81649	.57348	1.74375	10
51	.48450	2.06400	.50623	1.97538	.52836	1.89266	.55089	1.81524	.57386	1.74257	9
52	.48486	2.06247	.50660	1.97395	.52873	1.89133	.55127	1.81399	.57425	1.74140	8
53	.48521	2.06094	.50696	1.97253	.52910	1.89000	.55165	1.81274	.57464	1.74022	7
54	.48557	2.05942	.50733	1.97111	.52947	1.88867	.55203	1.81150	.57503	1.73905	6
55	.48593	2.05790	.50769	1.96969	.52985	1.88734	.55241	1.81025	.57541	1.73788	5
56	.48629	2.05637	.50806	1.96827	.53022	1.88602	.55279	1.80901	.57580	1.73671	4
57	.48665	2.05485	.50843	1.96685	.53059	1.88469	.55317	1.80777	.57619	1.73555	3
58	.48701	2.05333	.50879	1.96544	.53096	1.88337	.55355	1.80653	.57657	1.73438	2
59	.48737	2.05182	.50916	1.96402	.53134	1.88205	.55393	1.80529	.57696	1.73321	1
60	.48773	2.05030	.50953	1.96261	.53171	1.88073	.55431	1.80405	.57735	1.73205	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	64°		63°		62°		61°		60°		

′	30°		31°		32°		33°		34°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.57735	1.73205	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	60
1	.57774	1.73089	.60126	1.66318	.62527	1.59930	.64982	1.53888	.67493	1.48163	59
2	.57813	1.72973	.60165	1.66209	.62568	1.59826	.65024	1.53791	.67536	1.48070	58
3	.57851	1.72857	.60205	1.66099	.62608	1.59723	.65065	1.53693	.67578	1.47977	57
4	.57890	1.72741	.60245	1.65990	.62649	1.59620	.65106	1.53595	.67620	1.47885	56
5	.57929	1.72625	.60284	1.65881	.62689	1.59517	.65148	1.53497	.67663	1.47792	55
6	.57968	1.72509	.60324	1.65772	.62730	1.59414	.65189	1.53400	.67705	1.47699	54
7	.58007	1.72393	.60364	1.65663	.62770	1.59311	.65231	1.53302	.67748	1.47607	53
8	.58046	1.72278	.60403	1.65554	.62811	1.59208	.65272	1.53205	.67790	1.47514	52
9	.58085	1.72163	.60443	1.65445	.62852	1.59105	.65314	1.53107	.67832	1.47422	51
10	.58124	1.72047	.60483	1.65337	.62892	1.59002	.65355	1.53010	.67875	1.47330	50
11	.58162	1.71932	.60522	1.65228	.62933	1.58900	.65397	1.52913	.67917	1.47238	49
12	.58201	1.71817	.60562	1.65120	.62973	1.58797	.65438	1.52816	.67960	1.47146	48
13	.58240	1.71702	.60602	1.65011	.63014	1.58695	.65480	1.52719	.68002	1.47053	47
14	.58279	1.71588	.60642	1.64903	.63055	1.58593	.65521	1.52622	.68045	1.46962	46
15	.58318	1.71473	.60681	1.64795	.63095	1.58490	.65563	1.52525	.68088	1.46870	45
16	.58357	1.71358	.60721	1.64687	.63136	1.58388	.65604	1.52429	.68130	1.46778	44
17	.58396	1.71244	.60761	1.64579	.63177	1.58286	.65646	1.52332	.68173	1.46686	43
18	.58435	1.71129	.60801	1.64471	.63217	1.58184	.65688	1.52235	.68215	1.46595	42
19	.58474	1.71015	.60841	1.64363	.63258	1.58083	.65729	1.52139	.68258	1.46503	41
20	.58513	1.70901	.60881	1.64256	.63299	1.57981	.65771	1.52043	.68301	1.46411	40
21	.58552	1.70787	.60921	1.64148	.63340	1.57879	.65813	1.51946	.68343	1.46320	39
22	.58591	1.70673	.60960	1.64041	.63380	1.57778	.65854	1.51850	.68386	1.46229	38
23	.58631	1.70560	.61000	1.63934	.63421	1.57676	.65896	1.51754	.68429	1.46137	37
24	.58670	1.70446	.61040	1.63826	.63462	1.57575	.65938	1.51658	.68471	1.46046	36
25	.58709	1.70332	.61080	1.63719	.63503	1.57474	.65980	1.51562	.68514	1.45955	35
26	.58748	1.70219	.61120	1.63612	.63544	1.57372	.66021	1.51466	.68557	1.45864	34
27	.58787	1.70106	.61160	1.63505	.63584	1.57271	.66063	1.51370	.68600	1.45773	33
28	.58826	1.69992	.61200	1.63398	.63625	1.57170	.66105	1.51275	.68642	1.45682	32
29	.58865	1.69879	.61240	1.63292	.63666	1.57069	.66147	1.51179	.68685	1.45592	31
30	.58905	1.69766	.61280	1.63185	.63707	1.56969	.66189	1.51084	.68728	1.45501	30
31	.58944	1.69653	.61320	1.63079	.63748	1.56868	.66230	1.50988	.68771	1.45410	29
32	.58983	1.69541	.61360	1.62972	.63789	1.56767	.66272	1.50893	.68814	1.45320	28
33	.59022	1.69428	.61400	1.62866	.63830	1.56667	.66314	1.50797	.68857	1.45229	27
34	.59061	1.69316	.61440	1.62760	.63871	1.56566	.66356	1.50702	.68900	1.45139	26
35	.59101	1.69203	.61480	1.62654	.63912	1.56466	.66398	1.50607	.68942	1.45049	25
36	.59140	1.69091	.61520	1.62548	.63953	1.56366	.66440	1.50512	.68985	1.44958	24
37	.59179	1.68979	.61561	1.62442	.63994	1.56265	.66482	1.50417	.69028	1.44868	23
38	.59218	1.68866	.61601	1.62336	.64035	1.56165	.66524	1.50322	.69071	1.44778	22
39	.59258	1.68754	.61641	1.62230	.64076	1.56065	.66566	1.50228	.69114	1.44688	21
40	.59297	1.68643	.61681	1.62125	.64117	1.55966	.66608	1.50133	.69157	1.44598	20
41	.59336	1.68531	.61721	1.62019	.64158	1.55866	.66650	1.50038	.69200	1.44508	19
42	.59376	1.68419	.61761	1.61914	.64199	1.55766	.66692	1.49944	.69243	1.44418	18
43	.59415	1.68308	.61801	1.61808	.64240	1.55666	.66734	1.49849	.69286	1.44329	17
44	.59454	1.68196	.61842	1.61703	.64281	1.55567	.66776	1.49755	.69329	1.44239	16
45	.59494	1.68085	.61882	1.61598	.64322	1.55467	.66818	1.49661	.69372	1.44149	15
46	.59533	1.67974	.61922	1.61493	.64363	1.55368	.66860	1.49566	.69416	1.44060	14
47	.59573	1.67863	.61962	1.61388	.64404	1.55269	.66902	1.49472	.69459	1.43970	13
48	.59612	1.67752	.62003	1.61283	.64446	1.55170	.66944	1.49378	.69502	1.43881	12
49	.59651	1.67641	.62043	1.61179	.64487	1.55071	.66986	1.49284	.69545	1.43792	11
50	.59691	1.67530	.62083	1.61074	.64528	1.54972	.67028	1.49190	.69588	1.43703	10
51	.59730	1.67419	.62124	1.60970	.64569	1.54873	.67071	1.49097	.69631	1.43614	9
52	.59770	1.67309	.62164	1.60865	.64610	1.54774	.67113	1.49003	.69675	1.43525	8
53	.59809	1.67198	.62204	1.60761	.64652	1.54675	.67155	1.48909	.69718	1.43436	7
54	.59849	1.67088	.62245	1.60657	.64693	1.54576	.67197	1.48816	.69761	1.43347	6
55	.59888	1.66978	.62285	1.60553	.64734	1.54478	.67239	1.48722	.69804	1.43258	5
56	.59928	1.66867	.62325	1.60449	.64775	1.54379	.67282	1.48629	.69847	1.43169	4
57	.59967	1.66757	.62366	1.60345	.64817	1.54281	.67324	1.48536	.69891	1.43080	3
58	.60007	1.66647	.62406	1.60241	.64858	1.54183	.67366	1.48442	.69934	1.42992	2
59	.60046	1.66538	.62446	1.60137	.64899	1.54085	.67409	1.48349	.69977	1.42903	1
60	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.70021	1.42815	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	60
1	.70064	1.42726	.72699	1.37554	.75401	1.32624	.78175	1.27917	.81027	1.23416	59
2	.70107	1.42638	.72743	1.37470	.75447	1.32544	.78222	1.27841	.81075	1.23343	58
3	.70151	1.42550	.72788	1.37386	.75492	1.32464	.78269	1.27764	.81123	1.23270	57
4	.70194	1.42462	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196	56
5	.70238	1.42374	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123	55
6	.70281	1.42286	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050	54
7	.70325	1.42198	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977	53
8	.70368	1.42110	.73010	1.36967	.75721	1.32064	.78504	1.27382	.81364	1.22904	52
9	.70412	1.42022	.73055	1.36883	.75767	1.31984	.78551	1.27306	.81413	1.22831	51
10	.70455	1.41934	.73100	1.36800	.75812	1.31904	.78598	1.27230	.81461	1.22758	50
11	.70499	1.41847	.73144	1.36716	.75858	1.31825	.78645	1.27153	.81510	1.22685	49
12	.70542	1.41759	.73189	1.36633	.75904	1.31745	.78692	1.27077	.81558	1.22612	48
13	.70586	1.41672	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539	47
14	.70629	1.41584	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467	46
15	.70673	1.41497	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	45
16	.70717	1.41409	.73368	1.36300	.76088	1.31427	.78881	1.26774	.81752	1.22321	44
17	.70760	1.41322	.73413	1.36217	.76134	1.31348	.78928	1.26698	.81800	1.22249	43
18	.70804	1.41235	.73457	1.36134	.76180	1.31269	.78975	1.26622	.81849	1.22176	42
19	.70848	1.41148	.73502	1.36051	.76226	1.31190	.79022	1.26546	.81898	1.22104	41
20	.70891	1.41061	.73547	1.35968	.76272	1.31110	.79070	1.26471	.81946	1.22031	40
21	.70935	1.40974	.73592	1.35885	.76318	1.31031	.79117	1.26395	.81995	1.21959	39
22	.70979	1.40887	.73637	1.35802	.76364	1.30952	.79164	1.26319	.82044	1.21886	38
23	.71023	1.40800	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814	37
24	.71066	1.40714	.73726	1.35637	.76456	1.30795	.79259	1.26169	.82141	1.21742	36
25	.71110	1.40627	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670	35
26	.71154	1.40540	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598	34
27	.71198	1.40454	.73861	1.35389	.76594	1.30558	.79401	1.25943	.82287	1.21526	33
28	.71242	1.40367	.73906	1.35307	.76640	1.30480	.79449	1.25867	.82336	1.21454	32
29	.71285	1.40281	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382	31
30	.71329	1.40195	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310	30
31	.71373	1.40109	.74041	1.35060	.76779	1.30244	.79591	1.25642	.82483	1.21238	29
32	.71417	1.40022	.74086	1.34978	.76825	1.30166	.79639	1.25567	.82531	1.21166	28
33	.71461	1.39936	.74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	27
34	.71505	1.39850	.74176	1.34814	.76918	1.30009	.79734	1.25417	.82629	1.21023	26
35	.71549	1.39764	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951	25
36	.71593	1.39679	.74267	1.34650	.77010	1.29853	.79829	1.25268	.82727	1.20879	24
37	.71637	1.39593	.74312	1.34568	.77057	1.29775	.79877	1.25193	.82776	1.20808	23
38	.71681	1.39507	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736	22
39	.71725	1.39421	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665	21
40	.71769	1.39336	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593	20
41	.71813	1.39250	.74492	1.34242	.77242	1.29463	.80067	1.24895	.82972	1.20522	19
42	.71857	1.39165	.74538	1.34160	.77289	1.29385	.80115	1.24820	.83022	1.20451	18
43	.71901	1.39079	.74583	1.34079	.77335	1.29307	.80163	1.24746	.83071	1.20379	17
44	.71946	1.38994	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1.20308	16
45	.71990	1.38909	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237	15
46	.72034	1.38824	.74719	1.33835	.77475	1.29074	.80306	1.24523	.83218	1.20166	14
47	.72078	1.38738	.74764	1.33754	.77521	1.28997	.80354	1.24449	.83268	1.20095	13
48	.72122	1.38653	.74810	1.33673	.77568	1.28919	.80402	1.24375	.83317	1.20024	12
49	.72167	1.38568	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953	11
50	.72211	1.38484	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	10
51	.72255	1.38399	.74946	1.33430	.77708	1.28687	.80546	1.24153	.83465	1.19811	9
52	.72299	1.38314	.74991	1.33349	.77754	1.28610	.80594	1.24079	.83514	1.19740	8
53	.72344	1.38229	.75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669	7
54	.72388	1.38145	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599	6
55	.72432	1.38060	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	5
56	.72477	1.37976	.75173	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457	4
57	.72521	1.37891	.75219	1.32946	.77988	1.28225	.80834	1.23710	.83761	1.19387	3
58	.72565	1.37807	.75264	1.32865	.78035	1.28148	.80882	1.23637	.83811	1.19316	2
59	.72610	1.37722	.75310	1.32785	.78082	1.28071	.80930	1.23563	.83860	1.19246	1
60	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	.96625	1.03493	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	.96681	1.03433	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	.96738	1.03372	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	.96794	1.03312	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	.96850	1.03252	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	.96907	1.03192	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	.96963	1.03132	53
8	.84307	1.18614	.87338′	1.14498	.90463	1.10543	.93688	1.06738	.97020	1.03072	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	.97076	1.03012	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	.97133	1.02952	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	.97189	1.02892	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	.97246	1.02832	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	.97302	1.02772	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	.97359	1.02713	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	.97416	1.02653	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	.97472	1.02593	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	.97529	1.02533	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	.97586	1.02474	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	.97643	1.02414	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	.97700	1.02355	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	.97756	1.02295	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	.97813	1.02236	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	.97870	1.02176	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	.97927	1.02117	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	.97984	1.02057	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	.98041	1.01998	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	.98098	1.01939	33
28	.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	.98155	1.01879	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	.98213	1.01820	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	.98270	1.01761	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	.98327	1.01702	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	.98384	1.01642	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	.98441	1.01583	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	.98499	1.01524	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	.98556	1.01465	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	.98613	1.01406	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	.98671	1.01347	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	.98728	1.01288	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	.98786	1.01229	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	.98843	1.01170	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	.98901	1.01112	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	.98958	1.01053	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	.99016	1.00994	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	.99073	1.00935	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	.99131	1.00876	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	.99189	1.00818	14
47	.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	.99247	1.00759	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	.99304	1.00701	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	.99362	1.00642	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	.99420	1.00583	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	.99478	1.00525	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	.99536	1.00467	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	.99594	1.00408	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	.99652	1.00350	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	.99710	1.00291	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	.99768	1.00233	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	.99826	1.00175	3
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	.99884	1.00116	2
59	.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	.99942	1.00058	1
60	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	1.00000	1.00000	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	49°		48°		47°		46°		45°		

THE PROPERTIES OF SATURATED STEAM.

Pressure above Vacuum in Pounds per Square Inch.	Temperature, Fahrenheit Degrees.	Quantities of Heat in British Thermal Units.			Weight of a Cubic Foot of Steam in Pounds.	Volume.	
		Required to Raise Temperature of the Water from 32° to t.	Total Latent Heat at Pressure P.	Total Heat above 32°.		Of a Pound of Steam in Cubic Feet.	Ratio of Vol. of Steam to Vol. of Eq. Weight of Dist. Water at Temp. of Maximum Density.
1	2	3	4	5	6	7	8
p	t	q	L	H	W	V	R
1	102.018	70.040	1043.015	1113.055	.003027	330.4	20623
2	126.302	94.368	1026.094	1120.462	.005818	171.9	10730
3	141.654	109.764	1015.380	1125.144	.008522	117.3	7325
4	153.122	121.271	1007.370	1128.641	.011172	89.51	5588
5	162.370	130.563	1000.899	1131.462	.013781	72.56	4530
6	170.173	138.401	995.441	1133.842	.016357	61.14	3816
7	176.945	145.213	990.695	1135.908	.018908	52.89	3302
8	182.952	151.255	986.485	1137.740	.021436	46.65	2912
9	188.357	156.699	982.690	1139.389	.023944	41.77	2607
10	193.284	161.660	979.232	1140.892	.026437	37.83	2361
11	197.814	166.225	976.050	1142.275	.028911	34.59	2159
12	202.012	170.457	973.098	1143.555	.031376	31.87	1990
13	205.929	174.402	970.346	1144.748	.033828	29.56	1845
14	209.604	178.112	967.757	1145.869	.036265	27.58	1721
14.69	212.000	180.531	966.069	1146.600	.037928	26.37	1646
15	213.067	181.608	965.318	1146.926	.038688	25.85	1614
16	216.347	184.919	963.007	1147.926	.041109	24.33	1519
17	219.452	188.056	960.818	1148.874	.043519	22.98	1434
18	222.424	191.058	958.721	1149.779	.045920	21.78	1359
19	225.255	193.918	956.725	1150.643	.048312	20.70	1292

1	2	3	4	5	6	7	8
p	t	q	L	H	W	V	R
20	227.964	196.655	954.814	1151.469	.050696	19.73	1231.0
22	233.069	201.817	951.209	1153.026	.055446	18.04	1126.0
24	237.803	206.610	947.861	1154.471	.060171	16.62	1038.0
26	242.225	211.089	944.730	1155.819	.064870	15.42	962.3
28	246.376	215.293	941.791	1157.084	.069545	14.38	897.6
30	250.293	219.261	939.019	1158.280	.074201	13.48	841.3
32	254.002	223.021	936.389	1159.410	.078839	12.68	791.8
34	257.523	226.594	933.891	1160.485	.083461	11.98	748.0
36	260.883	230.001	931.508	1161.509	.088067	11.36	708.8
38	264.093	233.261	929.227	1162.488	.092657	10.79	673.7
40	267.168	236.386	927.040	1163.426	.097231	10.28	642.0
42	270.122	239.389	924.940	1164.329	.101794	9.826	613.3
44	272.965	242.275	922.919	1165.194	.106345	9.403	587.0
46	275.704	245.061	920.968	1166.029	.110884	9.018	563.0
48	278.348	247.752	919.084	1166.836	.115411	8.665	540.9
50	280.904	250.355	917.260	1167.615	.119927	8.338	520.5
52	283.381	252.875	915.494	1168.369	.124433	8.037	501.7
54	285.781	255.321	913.781	1169.102	.128928	7.756	484.2
56	288.111	257.695	912.118	1169.813	.133414	7.496	467.9
58	290.374	260.002	910.501	1170.503	.137892	7.252	452.7
60	292.575	262.248	908.928	1171.176	.142362	7.024	438.5
62	294.717	264.433	907.396	1171.829	.146824	6.811	425.2
64	296.805	266.566	905.900	1172.466	.151277	6.610	412.6
66	298.842	268.644	904.443	1173.087	.155721	6.422	400.8
68	300.831	270.674	903.020	1173.694	.160157	6.244	389.8
70	302.774	272.657	901.629	1174.286	.164584	6.076	379.3
72	304.669	274.597	900.269	1174.866	.169003	5.917	369.4
74	306.526	276.493	898.938	1175.431	.173417	5.767	360.0
76	308.344	278.350	897.635	1175.985	.177825	5.624	351.1
78	310.123	280.170	896.359	1176.529	.182229	5.488	342.6
80	311.866	281.952	895.108	1177.060	.186627	5.358	334.5
82	313.576	283.701	893.879	1177.580	.191017	5.235	326.8
84	315.250	285.414	892.677	1178.091	.195401	5.118	319.5
86	316.893	287.096	891.496	1178.592	.199781	5.006	312.5
88	318.510	288.750	890.335	1179.085	.204155	4.898	305.8

1	2	3	4	5	6	7	8
p	t	q	L	H	W	V	R
90	320.094	290.373	889.196	1179.569	.208525	4.796	299.4
92	321.653	291.970	888.075	1180.045	.212892	4.697	293.2
94	323.183	293.539	886.972	1180.511	.217253	4.603	287.3
96	324.688	295.083	885.887	1180.970	.221604	4.513	281.7
98	326.169	296.601	884.821	1181.422	.225950	4.426	276.3
100	327.625	298.093	883.773	1181.866	.230293	4.342	271.1
105	331.169	301.731	881.214	1182.945	.241139	4.147	258.9
110	334.582	305.242	878.744	1183.986	.251947	3.969	247.8
115	337.874	308.621	876.371	1184.992	.262732	3.806	237.6
120	341.058	311.885	874.076	1185.961	.273500	3.656	228.3
125	344.136	315.051	871.848	1186.899	.284243	3.518	219.6
130	347.121	318.121	869.688	1187.809	.294961	3.390	211.6
135	350.015	321.105	867.590	1188.695	.305659	3.272	204.2
140	352.827	324.003	865.552	1189.555	.316338	3.161	197.3
145	355.562	326.823	863.567	1190.390	.326998	3.058	190.9
150	358.223	329.566	861.634	1191.200	.337643	2.962	184.9
160	363.346	334.850	857.912	1192.762	.358886	2.786	173.9
170	368.226	339.892	854.359	1194.251	.380071	2.631	164.3
180	372.886	344.708	850.963	1195.671	.401201	2.493	155.6
190	377.352	349.329	847.703	1197.032	.422280	2.368	147.8
200	381.636	353.766	844.573	1198.339	.443310	2.256	140.8
210	385.759	358.041	841.556	1199.597	.464295	2.154	134.5
220	389.736	362.168	838.642	1200.810	.485237	2.061	128.7
230	393.575	366.152	835.828	1201.980	.506139	1.976	123.3
240	397.285	370.008	833.103	1203.111	.527003	1.898	118.5
250	400.883	373.750	830.459	1204.209	.547831	1.825	114.0
260	404.370	377.377	827.896	1205.273	.568626	1.759	109.8
270	407.755	380.905	825.401	1206.306	.589390	1.697	105.9
280	411.048	384.337	822.973	1207.310	.610124	1.639	102.3
290	414.250	387.677	820.609	1208.286	.630829	1.585	99.0
300	417.371	390.933	818.305	1209.238	.651506	1.535	95.8

MISCELLANEOUS TABLES.

SPECIFIC GRAVITIES AND WEIGHTS PER CUBIC FOOT.

METALS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Osmium	23.00	1,437.5
Platinum	21.50	1,343.8
Gold	19.50	1,218.8
Mercury	13.60	850.0
Lead (cast)	11.35	709.4
Silver	10.50	656.3
Copper (cast)	8.79	549.4
Brass	8.38	523.8
Wrought Iron	7.68	480.0
Cast Iron	7.21	450.0
Steel	7.84	490.0
Tin (cast)	7.29	455.6
Zinc (cast)	6.86	428.8
Antimony	6.71	419.4
Aluminum	2.50	156.3

WOODS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Ash	.845	52.80
Beech	.852	53.25
Cedar	.561	35.06
Cork	.240	15.00
Ebony (American)	1.331	83.19
Lignum-vitæ	1.333	83.30
Maple	.750	46.88
Oak (old)	1.170	73.10
Spruce	.500	31.25
Pine (yellow)	.660	41.20
Pine (white)	.554	34.60
Walnut	.671	41.90

LIQUIDS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Acetic Acid	1.062	66.4
Nitric Acid	1.217	76.1
Sulphuric Acid	1.841	115.1
Muriatic Acid	1.200	75.0
Alcohol	.800	50.0
Turpentine	.870	54.4
Sea Water (ordinary)	1.026	64.1
Milk	1.032	64.5

GASES.

At 32° F., and under a Pressure of One Atmosphere.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Atmospheric Air	1.0000	.08073
Carbonic Acid	1.5290	.12344
Carbonic Oxide	.9674	.07810
Chlorine	2.4400	.19700
Oxygen	1.1056	.08925
Nitrogen	.9736	.07860
Smoke (bituminous coal)	.1020	.00815
Smoke (wood)	.0900	.00727
*Steam at 212° F.	.4700	.03790
Hydrogen	.0692	.00559

* The specific gravity of steam at any temperature and pressure compared with air at the same temperature and pressure is 0.622.

MISCELLANEOUS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Emery	4.00	250
Glass (average)	2.80	175
Chalk	2.78	174
Granite	2.65	166
Marble	2.70	169
Stone (common)	2.52	158
Salt (common)	2.13	133
Soil (common)	1.98	124
Clay	1.93	121
Brick	1.90	118
Plaster Paris (average)	2.00	125
Sand	1.80	113

COEFFICIENTS OF FRICTION.

Description of Surfaces in Contact.	Disposition of Fibers.	State of the Surfaces.	Coefficient of Friction.
Oak on Oak	Parallel	Dry	.48
Oak on Oak	Parallel	Soaped	.16
Wrought Iron on Oak	Parallel	Dry	.62
Wrought Iron on Oak	Parallel	Soaped	.21
Cast Iron on Oak	Parallel	Dry	.49
Cast Iron on Oak	Parallel	Soaped	.19
Wrought Iron on Cast Iron	—	Slightly Unctuous	.18
Wrought Iron on Bronze	—	Slightly Unctuous	.18
Cast Iron on Cast Iron	—	Slightly Unctuous	.15

SPECIFIC HEATS OF SUBSTANCES.

SOLIDS.

Copper	0.0951	Cast Iron	0.1298
Gold	0.0324	Lead	0.0314
Wrought Iron	0.1138	Platinum	0.0324
Steel (soft)	0.1165	Silver	0.0570
Steel (hard)	0.1175	Tin	0.0562
Zinc	0.0956	Ice	0.5040
Brass	0.0939	Sulphur	0.2026
Glass	0.1937	Charcoal	0.2410

LIQUIDS.

Water	1.0000	Lead (melted)	0.0402
Alcohol	0.7000	Sulphur "	0.2340
Mercury	0.0333	Tin "	0.0637
Benzine	0.4500	Sulphuric Acid	0.3350
Glycerine	0.5550	Oil of Turpentine	0.4260

GASES.

	Constant Pressure.	Constant Volume.
Air	0.23751	0.16847
Oxygen	0.21751	0.15507
Nitrogen	0.24380	0.17273
Hydrogen	3.40900	2.41226
Superheated Steam	0.48050	0.34600
Carbonic Oxide	0.24790	0.17580
Carbonic Acid	0.40400	0.15350

TEMPERATURE AND LATENT HEATS OF FUSION AND VAPORIZATION.

Substance.	Temperature of Fusion.	Temperature of Vaporization.	Latent Heat of Fusion.	Latent Heat of Vaporization.
Water	32°	212°	142.65	966.6
Mercury	−37.8°	662°	5.09	157
Sulphur	228.3°	824°	13.26	
Tin	446°	....	25.65	
Lead	626°	....	9.67	
Zinc	680°	1,900°	50.63	493
Alcohol	Unknown	173°	....	372
Oil of Turpentine	14°	313°	....	124
Linseed Oil	....	600°		
Aluminum	1,400°			
Copper	2,100°			
Cast Iron	2,192°	3,300°		
Wrought Iron	2,912°	5,000°		
Steel	2,520°			
Platinum	3,632°			
Iridium	4,892°			

VOLUMES AND WEIGHTS OF GASES.

Gas.	Volume of 1 lb. at 32° F. and a Tension of 1 Atmosphere (14.7 lb. per sq. in.). Cu. Ft.	Weight of 1 Cu. Ft. at 32° F. and a Tension of 1 Atmosphere (14.7 lb. per sq. in.). Lb.	R.
Air	12.3880	.08073	.37052
Oxygen	11.2056	.08925	.33552
Nitrogen	12.7226	.07860	.38143
Hydrogen	178.8910	.00559	5.34946

COEFFICIENTS OF EXPANSION.

Name of Substance.	Linear Expansion.	Surface Expansion.	Cubic Expansion.
Cast Iron	.00000617	.00001234	.00001850
Copper	.00000955	.00001910	.00002864
Brass	.00001037	.00002074	.00003112
Silver	.00000690	.00001390	.00002070
Bar Iron	.00000686	.00001372	.00002058
Steel (untempered)	.00000599	.00001198	.00001798
Steel (tempered)	.00000702	.00001404	.00002106
Zinc	.00001634	.00003268	.00004903
Tin	.00001410	.00002820	.00004229
Mercury	.00003334	.00006668	.00010010
Alcohol	.00019259	.00038518	.00057778
Gases	.....	.....	.00203252

BOILING POINT AND LATENT AND SPECIFIC HEATS OF VARIOUS SUBSTANCES.

Substance.	Temperature of Boiling Point.	Latent Heat, B. T. U.	Specific Heat of Liquid.
Nitric Acid	248° F.	....	....
Saturated Brine	226° F.	....	....
Water	212° F.	966	1.0000
Alcohol	173° F.	....	....
Chloroform	140° F.	....	....
Ether, Sulphurous	95° F.	170	.5299
Ether, Methyl	— 10° F.	....	....
Sulphur Dioxide	14° F.	168.7	.4100
Anhydrous Ammonia	— 28.5° F.	573	1.0058
Carbon Dioxide	— 140° F.	141	.9550

Under a pressure of 342 pounds per square inch, carbon dioxide boils at a temperature of 5°. Its latent heat under the same conditions is 121.5.

PROPERTIES OF SATURATED VAPORS.

AMMONIA.

TEMPERATURE. Degrees F. t	PRESSURE, ABSOLUTE. Lb. per Sq. In. p	Heat of Vaporization, Thermal Units. r	Volume of Vapor per Lb., Cu. Ft. v	Volume of Liquid per Lb., Cu. Ft. v_1	Weight of a Cu. Ft. of Vapor, Pounds. w
− 40	10.69	579.67	24.3700	.0234	.0410
− 35	12.31	576.69	21.2900	.0236	.0467
− 30	14.13	573.69	18.6600	.0237	.0535
− 25	16.17	570.68	16.4100	.0238	.0609
− 20	18.45	567.67	14.4800	.0240	.0690
− 15	20.99	564.64	12.8100	.0242	.0779
− 10	23.77	561.61	11.3600	.0243	.0878
− 5	26.93	558.56	10.1200	.0244	.0988
0	30.37	555.50	9.0400	.0246	.1109
+ 5	34.17	552.43	8.0600	.0247	.1241
+ 10	38.55	549.35	7.2300	.0249	.1384
+ 15	42.93	546.26	6.4900	.0250	.1540
+ 20	47.95	543.15	5.8400	.0252	.1712
+ 25	53.43	540.03	5.2600	.0253	.1901
+ 30	59.41	536.92	4.7500	.0254	.2105
+ 35	65.93	533.78	4.3100	.0256	.2320
+ 40	73.00	530.63	3.9100	.0257	.2588
+ 45	80.66	527.47	3.5600	.0260	.2809
+ 50	88.96	524.30	3.2500	.0260	.3076
+ 55	97.93	521.12	2.9600	.0260	.3378
+ 60	107.60	517.93	2.7000	.0265	.3704
+ 65	118.03	514.73	2.4800	.0266	.4034
+ 70	129.21	511.52	2.2700	.0268	.4405
+ 75	141.25	508.29	2.0800	.0270	.4808
+ 80	154.11	504.66	1.9100	.0272	.5236
+ 85	167.86	501.81	1.7700	.0273	.5649
+ 90	182.80	498.11	1.6400	.0274	.6098
+ 95	198.37	495.29	1.5100	.0277	.6622
+ 100	215.14	491.50	1.3900	.0279	.7194
+ 105	232.98	488.72	1.2890	.0281	.7757
+ 110	251.97	485.42	1.2030	.0283	.8312
+ 115	272.14	482.41	1.1210	.0285	.8912
+ 120	293.49	478.79	1.0410	.0287	.9608
+ 125	316.16	475.45	.9699	.0289	1.0310
+ 130	340.42	472.11	.9051	.0291	1.1048
+ 135	365.16	468.75	.8457	.0293	1.1824
+ 140	392.22	465.39	.7910	.0295	1.2642
+ 145	420.49	462.01	.7408	.0297	1.3497
+ 150	450.20	458.62	.6946	.0299	1.4396
+ 155	481.54	455.22	.6511	.0302	1.5358
+ 160	514.40	451.81	.6128	.0304	1.6318
+ 165	549.04	448.39	.5765	.0306	1.7344

SULPHUR DIOXIDE.

Temperature of Ebullition in Deg. F.	Absolute Pressure in Lb. per Sq. In.	Total Heat Reckoned from 32° Fahr.	Heat of Liquid Reckoned from 32° Fahr.	Latent Heat of Vaporization.	Density of Vapor or Weight of 1 Cubic Ft.
Deg. F.	Lb.	B. T. U.	B. T. U.	B. T. U.	Lb.
−40	3.16	155.22	−17.76	172.98	.048
−31	4.23	156.39	−16.55	172.94	.062
−22	5.56	157.55	−15.05	172.60	.079
−13	7.23	158.69	−13.26	171.95	.099
− 4	9.27	159.82	−11.18	171.00	.124
5	11.76	160.93	− 8.82	169.75	.154
14	14.75	162.02	− 6.17	168.19	.190
23	18.31	163.10	− 3.23	166.33	.232
32	22.53	164.16	0.00	164.16	.282
41	27.48	165.21	3.52	161.69	.341
50	33.26	166.24	7.32	158.92	.410
59	39.93	167.25	11.41	155.84	.491
68	47.62	168.25	15.79	152.46	.584
77	56.39	169.23	20.45	148.78	.692
86	66.37	170.20	25.41	144.79	.819
95	77.64	171.15	30.65	140.50	.965
104	90.32	172.08	36.18	135.90	1.131

CARBON DIOXIDE.

Temperature of Ebullition in Deg. F.	Absolute Pressure in Lb. per Sq. In.	Total Heat from 32° F.	Heat of Liquid from 32° F.	Latent Heat of Vaporization.	Density of Vapor, or Weight of 1 Cu. Ft.
Deg. F.	Lb.	B. T. U.	B. T. U.	B. T. U.	Lb.
— 22	210	98.35	— 37.80	136.15	2.321
— 13	249	99.14	— 32.51	131.65	2.759
— 4	292	99.88	— 26.91	126.79	3.265
5	342	100.58	— 20.92	121.50	3.853
14	396	101.21	— 14.49	115.70	4.535
23	457	101.81	— 7.56	109.37	5.331
32	525	102.35	0.60	102.35	6.265
41	599	102.84	8.32	94.52	7.374
50	680	103.24	17.60	85.64	8.708
59	768	103.59	28.22	75.37	10.356
68	864	103.84	40.86	62.98	12.480
77	968	103.95	57.06	46.89	15.475
86	1,080	103.72	84.44	19.28	21.519

PROPERTIES OF BRINE.

SALT BRINE.

Degrees Beaumé, 60° F.	Degrees on Salometer, 60° F.	Specific Gravity, 60° F.	Per Cent. of Salt by Weight.	Weight of One Gallon.	Weight of One Cubic Foot.	Freezing Point, Degrees F.	Specific Heat.
0	0	1.000	0	8.35	62.40	32.00	1.000
1	4	1.007	1	8.40	62.80	31.80	0.992
5	20	1.037	5	8.65	64.70	25.40	0.960
10	40	1.073	10	8.95	66.95	18.60	0.892
15	60	1.115	15	9.30	69.57	12.20	0.855
19	80	1.150	20	9.60	71.76	6.86	0.829
	100	1.191	25	9.94	74.26	1.00	0.783

CALCIUM BRINE.

Degrees Beaumé, 60° F.	Specific Gravity, 60° F.	Per Cent. of Calcium.	Freezing Point, Degrees F.	Degrees Beaumé, 60° F.	Specific Gravity, 60° F.	Per Cent. of Calcium.	Freezing Point, Degrees F.	Specific Heat.
1	1.007	1	+31.10	21	1.169	19	+ 1.76	
2	1.015	2	30.38	22	1.179	20	— 1.48	
3	1.024	3	29.48	23	1.189	21	— 4.90	.76
4	1.032	4	28.58	24	1.199	22	— 8.68	
5.5	1.041	5	27.68	25	1.209	23	—11.64	.75
6.5	1.049	6	26.60	26	1.219	24	—17.14	
8	1.058	7	25.52	27	1.229	25	—21.82	
9	1.067	8	24.26	28	1.240	26	—27.04	
10	1.076	9	22.82	29	1.250	27	—32.62	
11	1.085	10	21.38	30	1.261	28	—39.28	
12	1.094	11	19.76	31	1.272	29	—46.30	.693
13	1.103	12	18.14	32	1.283	30	—54.40	
14.5	1.112	13	16.34	33	1.294	31	—52.42	
15.5	1.121	14	14.36	34	1.305	32	—39.28	
17	1.131	15	12.20	35	1.316	33	—25.24	
18	1.140	16	10.04	35.5	1.327	34	— 9.76	
19	1.150	17	7.52	36.5	1.338	35	+ 2.84	
20	1.159	18	4.64	37.5	1.349	36	+14.36	

STRENGTH OF AMMONIA LIQUOR.

Percentage of Ammonia by Weight.	Specific Gravity.	Degrees Beaumé.	
		Water 10°.	Water 0°.
0	1.000	10.0	0
1	.993	11.0	1.0
2	.986	12.0	2.0
4	.979	13.0	3.0
6	.972	14.0	4.0
8	.966	15.0	5.0
10	.960	16.0	6.0
12	.953	17.1	7.0
14	.945	18.3	8.2
16	.938	19.5	9.2
18	.931	20.7	10.3
20	.925	21.7	11.2
22	.919	22.8	12.3
24	.913	23.9	13.2
26	.907	24.8	14.3
28	.902	25.7	15.2
30	.897	26.6	16.2
32	.892	27.5	17.3
34	.888	28.4	18.2
36	.884	29.3	19.1
38	.880	30.2	20.0

LOWEST SPECIFIC GRAVITY OF AQUA AMMONIA, IN DEGREES BEAUME.

Steam Pressure in Generator, Pounds.	Ammonia Condensing Pressure, Pounds.					
	100	120	135	150	165	180
60	13.5	15.0	16.0	16.5	17.0	18.0
70	12.5	14.0	15.0	16.0	16.5	17.0
80	12.0	13.0	14.5	15.0	15.5	16.0
90	11.0	12.0	13.0	13.5	14.5	15.0
100	....	11.5	12.5	13.5	14.0	14.5
120	....	....	11.5	12.0	13.0	13.5

SPECIFIC GRAVITY AND SPECIFIC HEAT OF WORT AT 60° F.

Strength, by Balling Saccharometer.	Specific Gravity.	Specific Heat.
8	1.0320	.944
9	1.0363	.937
10	1.0404	.930
11	1.0446	.923
12	1.0488	.916
13	1.0530	.909
14	1.0572	.902
15	1.0614	.895
16	1.0657	.888
17	1.0700	.881
18	1.0744	.874
19	1.0788	.867
20	1.0832	.861

HEAT TRANSMITTED THROUGH MATERIALS OF THE SAME AREA AND THICKNESS.

Pine	100
Mineral Wool	80
Granulated Cork	65
Wood-Ashes	50
Sawdust	55
Charcoal (powdered)	65
Cotton	35
Paper	25

VALUES OF THE COEFFICIENT *c* IN FORMULA 137.

Partition.	Thickness, Inches.	*c*.
Single Windows	..	12.0
Double Windows	..	7.0
Pine Wood	12	2.0
Mineral Wool	12	1.6
Granulated Cork	12	1.3
Wood-Ashes	12	1.0
Sawdust	12	1.1
Charcoal (powdered)	12	1.3
Cotton	12	0.7
Soft Paper Felt	12	0.5
Brick	4½	5.5
"	9	4.5
"	14	3.6
"	18	3.0
"	27	2.6
"	36	2.2
Stone (masonry)	6	6.2
"	12	5.5
"	18	5.0
"	24	4.5
"	30	4.3
"	36	4.1

SPECIFIC HEAT AND LATENT HEAT OF FREEZING OF VICTUALS.

Substance.	Specific Heat.	Latent Heat of Freezing, B. T. U.
Beef	.80	110
Veal	.70	90
Mutton	.80	110
Pork	.60	72
Eggs	.75	100
Vegetables	.90	125
Cream	.70	90
Milk	.90	125
Fish	.85	115
Lobster	.80	100
Oysters	.85	115
Chicken	.80	110

STORAGE TEMPERATURES OF VARIOUS PRODUCTS.

Article.	Storage Temperature.	Article.	Storage Temperature.
Apples	30°	Frozen Meat	20°
Berries	34°	Fish	15°
Butter	10°	Furs	5°
Beer	36°	Grapes	33°
Cheese	34°	Lemons	33°
Dried Fruit	36°	Oranges	33°
Eggs	30°	Peaches	34°
Fresh Meat	33°	Pears	33°

SCHEDULE OF TEST.

In making a complete efficiency test of a compression refrigerating-machine, the data and results contained in the items of the following schedule should be obtained. In making a capacity test only, the items marked * need not be observed.

General Data.

1. Date.
2. Duration of test.
3. Name of machine.
4. Class of machine.
5. Nominal capacity of machine.
6. Diameter of steam cylinder.
7. Stroke of steam cylinder.
8. Diameter of ammonia cylinder.
9. Stroke of ammonia cylinder.
10. Diameter of brine-pump, steam end.
11. Diameter of brine-pump, brine end.
12. Stroke of brine-pump.

Observations.

13. Average high ammonia pressure, gauge.
14. Average back ammonia pressure, gauge.
15. Average temperature of the brine inlet.
16. Average temperature of the brine outlet.
17. Average range of temperature of brine.
18. Weight of brine circulated per minute.

*19. Average temperature of condensing water at inlet.

*20. Average temperature of condensing water at outlet.

*21. Average range of temperature of condensing water.

*22. Weight of water circulated per minute through condenser.

*23. Weight of water circulated per minute through jackets.

*24. Average temperature of water entering jackets.

*25. Average temperature of water leaving jackets.

*26. Average range of temperature in jackets.
27. Average temperature in engine room.
28. Specific gravity of brine.
29. Specific heat of brine.
30. Revolutions per minute.
*31. Mean effective pressure, steam cylinder.
*32. Mean effective pressure, ammonia cylinder.

RESULTS.

*33. Average horsepower of steam cylinder.
*34. Average horsepower of ammonia cylinder.
*35. Average friction horsepower.
*36. Friction horsepower in per cent. of steam horsepower.
*37. Condensing water, gallons per minute per ton.
38. Ice-melting capacity, tons per twenty-four hours.
*39. Refrigerating effect, pounds of ice per pound of coal.

HEAT BALANCE.

40. Heat given to ammonia by brine per minute, B. T. U.
41. Heat given to ammonia by compressor per minute, B. T. U.
42. Total heat received by ammonia per minute, B. T. U.
43. Heat delivered to condenser by ammonia per minute, B. T. U.
44. Heat delivered to jackets by ammonia per minute, B. T. U.
45. Total heat rejected by ammonia per minute, B. T. U.
46. Difference between heat received and rejected, B. T. U.

FORMULAS.

FORMULAS USED IN MENSURATION.

THE PARALLELOGRAM.

h = altitude of parallelogram, expressed in any unit;
b = base of parallelogram, expressed in same unit;
A = area of parallelogram.

$$A = h\,b. \qquad \textbf{(44.)} \text{ Art. } \textbf{375.}$$

$$\left.\begin{aligned} h &= \frac{A}{b}. \\ b &= \frac{A}{h}. \end{aligned}\right\} \qquad \textbf{(46.)} \text{ Art. } \textbf{377.}$$

THE TRAPEZOID.

h = altitude of a trapezoid;
l = length of one of its parallel sides;
l_1 = length of the other parallel side;
A = area of trapezoid.

$$A = h\left(\frac{l + l_1}{2}\right). \qquad \textbf{(45.)} \text{ Art. } \textbf{376.}$$

THE TRIANGLE.

A, B, C = the number of degrees in the three angles, respectively.

$$\left.\begin{aligned} A &= 180° - B - C. \\ B &= 180° - A - C. \\ C &= 180° - B - A. \end{aligned}\right\} \qquad \textbf{(47.)} \text{ Art. } \textbf{382.}$$

A_1 and B_1 = the number of degrees in the two acute angles, respectively, of any right-angled triangle.

$$\left.\begin{aligned} A_1 &= 90° - B_1. \\ B_1 &= 90° - A_1. \end{aligned}\right\} \qquad \textbf{(48.)} \text{ Art. } \textbf{383.}$$

a and b = the lengths, respectively, of the two short sides of a right-angled triangle;

c = length of third side, or hypotenuse.

$$c = \sqrt{a^2 + b^2}. \qquad \textbf{(49.)} \text{ Art. } \textbf{385.}$$

$$\left.\begin{aligned} a &= \sqrt{c^2 - b^2}. \\ b &= \sqrt{c^2 - a^2}. \end{aligned}\right\} \qquad \textbf{(50.)} \text{ Art. } \textbf{385.}$$

h = altitude of given triangle;

b = base of triangle;

A = area of triangle.

$$A = \frac{b\,h}{2}. \qquad \textbf{(51.)} \text{ Art. } \textbf{386.}$$

$$\left.\begin{aligned} h &= \frac{2\,A}{b}. \\ b &= \frac{2\,A}{h}. \end{aligned}\right\} \qquad \textbf{(52.)} \text{ Art. } \textbf{386.}$$

THE POLYGON.

N = number of sides in any regular polygon.

D = number of degrees in each interior angle.

$$D = \frac{180\,(N-2)}{N}. \qquad \textbf{(53.)} \text{ Art. } \textbf{389.}$$

l = length of side of any regular polygon;

d = perpendicular distance from center of polygon (i.e. center of circumscribing circle) to any side;

N = number of sides;

A = area of polygon.

$$A = \frac{d\,l\,N}{2}. \qquad \textbf{(54.)} \text{ Art. } \textbf{390.}$$

THE CIRCLE.

d = diameter of circle;

c = circumference;

A = area;

l = length of arc;

n = number of degrees in arc;

a = area of sector;

a_1 = area of segment;
n_1 = number of degrees in sector;
$\pi = 3.1416$.

$$c = \pi d. \qquad \textbf{(55.)} \quad \text{Art. } \textbf{402.}$$

$$d = \frac{c}{\pi}. \qquad \textbf{(56.)} \quad \text{Art. } \textbf{403.}$$

$$l = \frac{c\,n}{360}. \qquad \textbf{(57.)} \quad \text{Art. } \textbf{404.}$$

$$A = \frac{\pi\,d^2}{4} = .7854\,d^2. \qquad \textbf{(58.)} \quad \text{Art. } \textbf{405.}$$

$$d = \sqrt{\frac{A}{.7854}}. \qquad \textbf{(59.)} \quad \text{Art. } \textbf{406.}$$

$$a = \frac{n_1 A}{360}. \qquad \textbf{(60.)} \quad \text{Art. } \textbf{407.}$$

$$a_1 = \frac{4\,h^2}{3}\sqrt{\frac{d}{h} - .608}. \qquad \textbf{(61.)} \quad \text{Art. } \textbf{408.}$$

THE PRISM, CYLINDER, CONE, AND PYRAMID.

p = perimeter of the base of the prism, cylinder, cone, or pyramid;
h = altitude;
h_1 = slant height of cone;
A = area of convex surface;
a = area of base;
A_1 = total area of outside surface;
V = volume.

Prism and cylinder $\left\{\begin{array}{l} A = p\,h. \\ A_1 = A + 2a. \\ V = a\,h. \end{array}\right.$

$$\textbf{(62.)} \quad \text{Art. } \textbf{416.}$$
$$\textbf{(63.)} \quad \text{Art. } \textbf{417.}$$

Pyramid and cone $\left\{\begin{array}{l} A = \frac{p\,h_1}{2}. \\ A_1 = A + a. \\ V = \frac{a\,h}{3}. \end{array}\right.$

$$\textbf{(64.)} \quad \text{Art. } \textbf{422.}$$
$$\textbf{(65.)} \quad \text{Art. } \textbf{423.}$$

FRUSTUM OF CONE OR PYRAMID.

p = perimeter of upper base of frustum;
p_1 = perimeter of lower base of frustum;
h = altitude of frustum;
h_1 = slant height;
a = area of upper base;
a_1 = area of lower base;
A = convex surface;
A_1 = total surface;
V = volume.

$$\left.\begin{aligned} A &= \left(\frac{p+p_1}{2}\right)h_1. \\ A_1 &= A + a + a_1. \end{aligned}\right\} \qquad \textbf{(66.)}\ \text{Art. } \textbf{426.}$$

$$V = (a + a_1 + \sqrt{a\,a_1})\frac{h}{3}. \qquad \textbf{(67.)}\ \text{Art. } \textbf{427.}$$

THE SPHERE.

a = diameter of sphere;
A = area of surface;
V = volume;
π = 3.1416.

$$A = \pi d^2. \qquad \textbf{(68.)}\ \text{Art. } \textbf{429.}$$

$$V = \frac{1}{6}\pi d^3 = .5236\, d^3. \qquad \textbf{(69.)}\ \text{Art. } \textbf{430.}$$

THE CYLINDRICAL RING.

a = area of cross-section of ring;
c = circumference of cross-section;
D = mean circumference of ring;
A = convex area of ring;
V = volume of ring.

$$A = Dc. \qquad \textbf{(70.)}\ \text{Art. } \textbf{431.}$$

$$V = Da. \qquad \textbf{(71.)}\ \text{Art. } \textbf{432.}$$

FORMULAS USED IN ELEMENTARY ALGEBRA AND TRIGONOMETRIC FUNCTIONS.

IMPORTANT ALGEBRAIC IDENTITIES.

$$(x+b)^2 = a^2 + 2ab + b^2. \quad (1.)$$
$$(a-b)^2 = a^2 - 2ab + b^2. \quad (2.)$$
$$(a+b)(a-b) = a^2 - b^2. \quad (3.)$$

Art. **497.**

TRIGONOMETRICAL RELATIONS.

The trigonometric functions are defined as follows:

$$\textit{Sine} = \frac{\textit{side opposite the angle}}{\textit{hypotenuse}}. \quad \text{Art. } \mathbf{594.}$$

$$\textit{Cosine} = \frac{\textit{side adjacent}}{\textit{hypotenuse}}. \quad \text{Art. } \mathbf{595.}$$

$$\textit{Tangent} = \frac{\textit{side opposite}}{\textit{side adjacent}}. \quad \text{Art. } \mathbf{596.}$$

$$\textit{Cotangent} = \frac{\textit{side adjacent}}{\textit{side opposite}}. \quad \text{Art. } \mathbf{597.}$$

The following relations between the sides and angles of a right triangle are derived directly from the definitions of the trigonometric functions. Art. **609.**

I. *Side opposite an angle = hypotenuse × sine of angle.*

II. *Side adjacent = hypotenuse × cosine.*

III. *Side opposite = side adjacent × tangent.*

IV. *Side adjacent = side opposite × cotangent.*

V. $\textit{Hypotenuse} = \frac{\textit{side opposite}}{\textit{sine}}$.

VI. $\textit{Hypotenuse} = \frac{\textit{side adjacent}}{\textit{cosine}}$.

Let a, b, and c denote the sides and A, B, and C the angles of any oblique-angled triangle; the angle A being opposite the side a, angle B opposite side b, etc.

Then, $\frac{a}{l} = \frac{\sin A}{\sin B}$, or $a : b = \sin A : \sin B$;

$\frac{b}{c} = \frac{\sin B}{\sin C}$, or $b : c = \sin B : \sin C$;

$\frac{c}{a} = \frac{\sin C}{\sin A}$, or $c : a = \sin C : \sin A$.

Rule.—*In any triangle, the sides are proportional to the sines of the opposite angles.* Art. **615.**

RULES USED IN LOGARITHMS.

RULES FOR THE CHARACTERISTIC.

I. *For a number greater than 1 the characteristic is one less than the number of integral places in the number.*

By "integral places" is meant the figures (including ciphers) to the left of the decimal point.

II. *For a number wholly decimal, the characteristic is negative, and is numerically one greater than the number of ciphers between the decimal point and the first digit of the decimal.* Art. **625.**

RULES FOR USING THE TABLE OF LOGARITHMS.

To Find the Logarithm of a Number Not Having More Than Four Figures.—*Find the first three significant figures of the number whose logarithm is desired, in the left-hand column; find the fourth figure in the column at the top (or bottom) of the page, and in the column under (or above) this figure, and opposite the first three figures previously found will be the mantissa or decimal part of the logarithm. The characteristic being found, write it at the left of the mantissa, and the resulting expression will be the logarithm of the required number.* Art. **627.**

To Find the Logarithm of a Number Consisting of Five or More Figures.—**I.** *If the number consists of more than five figures and the sixth figure is 5 or greater, increase*

the fifth figure by 1, and write ciphers in place of the sixth and remaining figures.

II. *Find the mantissa corresponding to the logarithm of the first four figures, and subtract this mantissa from the next greater mantissa in the table; the remainder is the difference.*

III. *Find in the secondary table headed P. P. a column headed by the same number as that just found for the difference, and in this column opposite the number corresponding to the fifth figure (or fifth figure increased by 1) of the given number (this figure is always situated at the left of the dividing line of the column) will be found the P. P. (proportional part) for that number. The P. P. thus found is to be added to the mantissa found in II, as in the preceding examples, and the result is the mantissa of the logarithm of the given number, as nearly as may be found with five-place tables.* Art. **636.**

To Find a Number Whose Logarithm Is Given.— **I.** *Consider the mantissa first. Glance along the different columns of the table which are headed 0 until the first two figures of the mantissa are found. Then glance down the same column until the third figure is found (or 1 less than the third figure). Having found the first three figures, glance to the right along the row in which they are situated until the last three figures of the mantissa are found. Then, the number which heads the column in which the last three figures of the mantissa are found is the fourth figure of the required number, and the first three figures lie in the column headed N, and in the same row in which lie the last three figures of the mantissa.*

II. *If the mantissa cannot be found in the table, find the mantissa which is nearest to, but less than, the given mantissa, and which call the* **next less mantissa.** *Subtract the next less mantissa from the next greater mantissa in the table to obtain the difference. Also subtract the next less mantissa from the mantissa of the given logarithm, and call the remainder the P. P. Looking in the secondary table headed P. P. for*

the column headed by the difference just found, find the number opposite the P. P. just found (or the P. P. corresponding most nearly to that just found); this number is the fifth figure of the required number; the fourth figure will be found at the top of the column containing the next less mantissa, and the first three figures in the column headed N and in the same row which contains the next less mantissa.

III. *Having found the figures of the number as above directed, locate the decimal point by the rules for the characteristic, annexing ciphers to bring the number up to the required number of figures if the characteristic is greater than 4.* Art. **638.**

MULTIPLICATION BY LOGARITHMS.

Rule.—*To multiply two or more numbers by using logarithms, add the logarithms of the several numbers, and the sum will be the logarithm of the product. Find the number corresponding to this logarithm, and the result will be the number sought.* Art. **647.**

DIVISION BY LOGARITHMS.

Rule.—*To divide one number by another by means of logarithms, subtract the logarithm of the divisor from the logarithm of the dividend; the result will be the logarithm of the quotient.* Art. **652.**

INVOLUTION BY LOGARITHMS.

Rule.—*To raise a number to any power by the use of logarithms, multiply the logarithm of the number by the exponent which denotes the power to which the number is to be raised; the result will be the logarithm of the required power.* Art. **657.**

If the number is wholly decimal, so that the characteristic is negative, *multiply the two parts of the logarithm separately by the exponent of the number. If, after multiplying*

the mantissa, the product has a characteristic, add it, algebraically, to the negative characteristic, multiplied by the exponent, and the result will be the negative characteristic of the required power. Art. **658.**

EVOLUTION BY LOGARITHMS.

Rule.—*To extract any root of a number by means of logarithms, divide the number by the index of the root; the result will be the logarithm of the root.* Art. **662.**

If it is required to extract a root of a number wholly decimal, and the negative characteristic will not exactly contain the index of the root, without a remainder, proceed as follows:

Separate the two parts of the logarithm; add as many units (or parts of a unit) to the negative characteristic as will make it exactly contain the index of the root. Add the same number to the mantissa, and divide both parts by the index. The result will be the characteristic and mantissa of the root. Art. **663.**

FORMULAS USED IN ELEMENTARY MECHANICS.

UNIFORM MOTION.

Let S = the length of space passed over uniformly;
t = the time occupied in passing over the space S;
V = the velocity.

$$V = \frac{S}{t}. \qquad (7.) \text{ Art. } \mathbf{859.}$$

$$S = Vt. \qquad (8.) \text{ Art. } \mathbf{859.}$$

$$t = \frac{S}{V}. \qquad (9.) \text{ Art. } \mathbf{859.}$$

MASS, WEIGHT, AND GRAVITY.

If the mass of the body be represented by m, its weight by W, and the force of gravity at the place where the body was weighed by g, we have

$$\text{mass} = \frac{\text{weight of body}}{\text{force of gravity}}, \text{ or } m = \frac{W}{g}. \qquad \textbf{(10.)} \text{ Art. } \textbf{888.}$$

FORMULAS FOR GRAVITY PROBLEMS.

Let W = weight of body at the surface;
w = weight of a body at a given distance above or below the surface;
d = distance between the center of the earth and the center of the body;
R = radius of the earth = 4,000 miles.

Formula for weight when the body is below the surface:

$$w R = d W. \qquad \textbf{(11.)} \text{ Art. } \textbf{891.}$$

Formula for weight when the body is above the surface.

$$w d^2 = W R^2. \qquad \textbf{(12.)} \text{ Art. } \textbf{891.}$$

FALLING BODIES.

Let g = force of gravity = constant accelerating force due to the attraction of the earth;
t = number of seconds the body falls;
v = velocity at the end of the time t;
h = distance that a body falls during the time t.

$$v = g t. \qquad \textbf{(13.)} \text{ Art. } \textbf{896.}$$

That is, the velocity acquired by a freely falling body at the end of t seconds equals 32.16 multiplied by the time in seconds.

$$t = \frac{v}{g}. \qquad \textbf{(14.)} \text{ Art. } \textbf{896.}$$

That is, the number of seconds during which a body must have fallen to acquire a given velocity equals the given velocity in feet per second divided by 32.16.

$$h = \frac{v^2}{2g}. \qquad \textbf{(15.)} \quad \text{Art. } \textbf{896.}$$

That is, the height from which a body must fall to acquire a given velocity equals the square of the given velocity divided by 2 × 32.16.

$$v = \sqrt{2gh}. \qquad \textbf{(16.)} \quad \text{Art. } \textbf{896.}$$

That is, the velocity that a body will acquire in falling through a given height equals the square root of the product of twice 32.16 and the given height.

$$h = \tfrac{1}{2} g t^2. \qquad \textbf{(17.)} \quad \text{Art. } \textbf{896.}$$

That is, the distance a body will fall in a given time equals 32.16 ÷ 2 multiplied by the square of the number of seconds.

$$t = \sqrt{\frac{2h}{g}}. \qquad \textbf{(18.)} \quad \text{Art. } \textbf{896.}$$

That is, the time it will take a body to fall through a given height equals the square root of twice the height divided by 32.16.

CENTRIFUGAL FORCE.

The value of the centrifugal force of any revolving body, expressed in pounds, is

$$F = .00034\ W R N^2; \qquad \textbf{(19.)} \quad \text{Art. } \textbf{903.}$$

in which F = centrifugal force;
W = total weight of body in pounds;
R = radius, usually taken as the distance between the center of motion and the center of gravity of the revolving body, in feet;
N = number of revolutions per *minute*.

THE CENTER OF GRAVITY OF TWO BODIES.

Let l = the distance between the centers of the bodies;
l_1 = the short arm;
w = weight of small body;
W = weight of large body.

$$l_1 = \frac{w\,l}{W + w}. \qquad \textbf{(20.)} \quad \text{Art. } \textbf{911.}$$

THE EFFICIENCY OF A MACHINE.

Let F = the force applied to the machine;
V = the velocity ratio of the machine;
W = the weight actually lifted or equivalent resistance overcome;
E = the efficiency of the machine;

$$\text{Then, } \mathsf{E} = \frac{W}{F\,V}. \qquad \textbf{(22.)} \quad \text{Art. } \textbf{950.}$$

WORK.

If the force necessary to overcome the resistance be represented by F, the space through which the resistance acts by S, and the work done by U, then $U = F\,S$.

If W = the weight of a body, and h = the height through which it is raised, $U = W\,h$. Hence the work done

$$U = F\,S = W\,h. \qquad \textbf{(23.)} \quad \text{Art. } \textbf{953.}$$

POWER.

The power of a machine may always be determined by *dividing the work done in foot-pounds by the time in minutes required to do the work; i. e.,*

$$\text{Power} = \frac{F\,S}{T}. \qquad \textbf{(24.)} \quad \text{Art. } \textbf{954.}$$

KINETIC ENERGY.

Let W = the weight of the body in pounds;
v = its velocity in feet per second;
h = the height in feet through which the body must fall to produce the velocity v;
m = the mass of the body $= \frac{W}{g}$. (See formula **10.**)

The work necessary to raise a body through a height h is Wh. The velocity produced in falling a height h is $v = \sqrt{2gh}$, and $h = \frac{v^2}{2g}$. (See formulas **15** and **16.**)

Therefore, work $= Wh = W\frac{v^2}{2g} = \frac{1}{2} \times \frac{W}{g} \times v^2 = \frac{1}{2} m v^2$, or

$$Wh = \tfrac{1}{2} m v^2. \qquad \textbf{(25.)} \quad \text{Art. } \textbf{957.}$$

DENSITY.

Let D equal the density, m the mass, and W the weight, and V the volume (in cu. ft.) of a body. Then

$$D = \frac{m}{V}. \quad \text{Since } m = \frac{W}{g}, \; D = \frac{W}{gV}. \qquad \textbf{(26.)} \quad \text{Art. } \textbf{962.}$$

FORMULAS USED IN PNEUMATICS.

PRESSURE, VOLUME, DENSITY, AND WEIGHT OF AIR WHEN THE TEMPERATURE IS CONSTANT.

Mariotte's Law.—*The temperature remaining the same, the volume of a given quantity of gas varies inversely as the pressure.*

Let p = pressure for one position of the piston;
p_1 = pressure for any other position of the piston;
v = volume corresponding to the pressure p;
v_1 = volume corresponding to the pressure p_1.

Then, $p\,v = p_1\,v_1$. **(53.)** Art. **1049.**

Let D be the density corresponding to the pressure p and volume v, and D_1 be the density corresponding to the pressure p_1 and volume v_1; then,

$p : D = p_1 : D_1$, or $p\,D_1 = p_1\,D$, **(54.)** Art. **1052.**

and $v : D_1 = v_1 : D$, or $v\,D = v_1\,D_1$. **(55.)** Art. **1052.**

Thus, let W be the weight of a cubic foot of air or other gas, whose volume is v, and pressure is p; let W_1 be the weight of a cubic foot when the volume is v_1, and pressure is p_1; then,

$p\,W_1 = p_1\,W$. **(56.)** Art. **1052.**

$v\,W = v_1\,W_1$. **(57.)** Art. **1052.**

PRESSURE AND VOLUME OF A GAS WITH VARIABLE TEMPERATURE.

Gay-Lussac's Law.—*If the pressure remains constant, every increase of temperature of 1° F. produces in a given quantity of gas an expansion of $\frac{1}{491}$ of its volume at 32° F.*

If the pressure remains constant it will also be found that every decrease of temperature of 1° F. will cause a decrease of $\frac{1}{491}$ of the volume at 32° F.

Let v = original volume of gas;
v_1 = final volume of gas;
t = temperature corresponding to volume v;
t_1 = temperature corresponding to volume v.

Then, $$v_1 = v\left(\frac{460 + t_1}{460 + t}\right). \qquad \textbf{(58.)}$$ Art. **1054.**

That is, *the volume of gas after heating (or cooling) equals the original volume multiplied by 460 plus the final temperature divided by 460 plus the original temperature.*

Let p = the original tension;
t = the corresponding temperature;
p_1 = final tension;
t_1 = final temperature.

Then, $$p_1 = p\left(\frac{460 + t_1}{460 + t}\right). \qquad \textbf{(59.)}$$ Art. **1055.**

Let p = pressure in pounds per square inch;
V = volume of air in cubic feet;
T = absolute temperature;
W = weight in pounds.

Then, $$p\,V = .37052\,T. \qquad \textbf{(60.)}$$ Art. **1056.**

If the weight of the air be greater or less than 1 pound, the following formula must be used:

$$p\,V = .37052\,W\,T. \qquad \textbf{(61.)}$$ Art. **1057.**

Let p_1, V_1, and T_1 represent the pressure, volume, and temperature of the same weight of air in another state; then,

$$\frac{p\,V}{T} = \frac{p_1\,V_1}{T_1}. \qquad \textbf{(62.)}$$ Art. **1058.**

MIXTURE OF TWO GASES HAVING UNEQUAL VOLUMES AND PRESSURES.

Let v and p be the volume and pressure, respectively, of one of the gases.

Let v_1 and p_1 be the volume and pressure, respectively, of the other gas.

Let V and P be the volume and pressure, respectively, of the mixture. Then, if the temperature remains the same,

$$V P = v p + v_1 p_1. \quad \textbf{(63.)} \quad \text{Art. } \textbf{1062.}$$

MIXTURE OF TWO VOLUMES OF AIR HAVING UNEQUAL PRESSURES, VOLUMES, AND TEMPERATURES.

If a body of air having a temperature t_1, a pressure p_1, and a volume v_1, be mixed with another volume of air having a temperature t_2, a pressure p_2, and a volume v_2, to form a volume V having a pressure P, and a temperature t, then, either the new temperature t, the new volume V, or the new pressure P may be found, if the other two quantities are known, by the following formula, in which T_1, T_2, and T are the absolute temperatures corresponding to t_1, t_2, and t:

$$PV = \left[\frac{p_1 v_1}{T_1} + \frac{p_2 v_2}{T_2}\right] T. \quad \textbf{(64.)} \quad \text{Art. } \textbf{1063.}$$

FORMULAS USED IN HEAT.

TO CHANGE FAHRENHEIT TEMPERATURES TO CENTIGRADE, AND CENTIGRADE TO FAHRENHEIT.

Let t_c = temperature Centigrade, and t_f = temperature Fahrenheit. Then,

$$t_f = \tfrac{9}{5}\, t_c + 32°, \quad \textbf{(65.)} \quad \text{Art. } \textbf{1104.}$$

$$\text{and } t_c = (t_f - 32°)\, \tfrac{5}{9}. \quad \textbf{(66.)} \quad \text{Art. } \textbf{1104.}$$

EXPANSION OR CONTRACTION OF BODIES FROM CHANGES OF TEMPERATURE.

Let L = length of any body;

l = amount of expansion or contraction due to heating or cooling the body;

A = area of any section of the body;

a = increase or decrease of area of the same section after heating or cooling the body;
V = volume of the body;
v = increase or decrease in volume due to heating or cooling the body;
C_1 = coefficient of expansion taken from column 1, Table 1;
C_2 = coefficient taken from column 2, Table 1;
C_3 = coefficient taken from column 3, Table 1;
t = difference in degrees of temperature between the original temperature and the temperature of the body after it has been heated or cooled.

Then, $l = L\,C_1\,t$; **(67.)** Art. **1113.**

$a = A\,C_2\,t$; **(68.)** Art. **1113.**

$v = V\,C_3\,t$. **(69.)** Art. **1113.**

RESULTING TEMPERATURES AND SPECIFIC HEATS OF THE MIXTURE OF SEVERAL BODIES HAVING UNEQUAL TEMPERATURES.

$$t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2 + W_3 s_3 t_3 + \text{etc.}}{W_1 s_1 + W_2 s_2 + W_3 s_3 + \text{etc.}}, \quad \left\{ \begin{array}{l} \textbf{(73.)} \\ \text{Art. } \textbf{1136.} \end{array} \right.$$

$$\text{or } s_3 = \frac{W_1 s_1 (t_1 - t) + W_2 s_2 (t_2 - t) + \text{etc.}}{W_3 (t - t_3)}, \quad \left\{ \begin{array}{l} \textbf{(74.)} \\ \text{Art. } \textbf{1137.} \end{array} \right.$$

in which t is the final temperature of the mixture; W_1, s_1, and t_1, the weight, specific heat, and temperature, respectively, of one body; W_2, s_2, and t_2 the same for second body; and W_3, s_3, and t_3 the same for a third body, etc.

WORK DONE BY THE ISOTHERMAL EXPANSION OF A GAS.

L = the work in foot-pounds;
P = the total initial pressure in pounds per square foot;
P_1 = the total final pressure in pounds per square foot;
V = the initial volume in cubic feet;
V_1 = the final volume in cubic feet.

$$L = 2.3026\,P V \log \frac{V_1}{V}. \qquad \textbf{(75.)} \text{ Art. } \textbf{1160.}$$

Since $PV = P_1 V_1$, $\frac{P}{P_1} = \frac{V_1}{V}$, and formula **75** might be written

$$L = 2.3026\, PV \log \frac{P}{P_1}. \qquad \textbf{(76.)} \quad \text{Art. } \textbf{1160.}$$

Whichever formula is used it must be kept in mind that the fraction $\frac{V_1}{V}$ or $\frac{P}{P_1}$ must *always be greater than 1; that is, the numerator must always be greater than the denominator.*

WORK REQUIRED TO COMPRESS A GAS ISOTHERMALLY.

$$L = 2.3026\, PV \log \frac{V}{V_1}, \qquad \textbf{(77.)}$$

$$L = 2.3026\, PV \log \frac{P_1}{P}, \qquad \textbf{(78.)} \quad \text{Art. } \textbf{1162.}$$

in which the letters have the same meaning as before, and *the larger volume or pressure is always in the numerator.*

Formulas **75, 76, 77,** and **78** will be easier to use if the pressure be taken in pounds per square inch, and $144 \times 2.3026 = 331.5744$ be substituted for 2.3026. As before, the volume must always be taken in cubic feet. Formulas **75** and **76** then become

$$L = 331.5744\, p\, V \log \frac{V_1}{V}, \qquad \textbf{(79.)}$$

$$L = 331.5744\, p\, V \log \frac{p}{p_1}, \qquad \textbf{(80.)} \quad \text{Art. } \textbf{1163.}$$

in which p = pressure in pounds per square inch.

RELATION BETWEEN PRESSURES AND VOLUMES OF AIR DURING ADIABATIC EXPANSION OR COMPRESSION.

Let p and v = the volume and pressure during one stage;

p_1 and v_1 = the volume and pressure during the next stage;

p_2 and v_2 = the volume and pressure during the third stage, etc.;

then $p v^{1.41} = p_1 v_1^{1.41} = p_2 v_2^{1.41} = \text{etc.}$ **(81.)** Art. **1164.**

WORK DONE BY THE ADIABATIC EXPANSION OF AIR.

Let L = work in foot-pounds;
P = initial pressure in pounds per square foot;
P_1 = final pressure in pounds per square foot;
V = initial volume in cubic feet;
V_1 = final volume in cubic feet.

$$L = 2.44\,PV\left[1 - \left(\frac{V}{V_1}\right)^{.41}\right], \qquad \textbf{(82.)}\ \text{Art. } \textbf{1165.}$$

$$L = 2.44\,PV\left[1 - \left(\frac{P_1}{P}\right)^{.29078}\right]. \qquad \textbf{(83.)}\ \text{Art. } \textbf{1166.}$$

Let p and p_1 be the initial and final pressures, respectively, in pounds per square inch, then,

$$L = 351.36\,pV\left[1 - \left(\frac{V}{V_1}\right)^{.41}\right], \qquad \textbf{(84.)}$$

$$L = 351.36\,pV\left[1 - \left(\frac{p_1}{p}\right)^{.29078}\right]. \qquad \textbf{(85.)}\ \text{Art. } \textbf{1167.}$$

The relation between the pressures and temperatures, and the volumes and temperatures, during the adiabatic expansion of air, are given by the following formulas:

$$\left(\frac{P}{P_1}\right)^{.29078} = \frac{T}{T_1}. \qquad \textbf{(86.)}\ \text{Art. } \textbf{1170.}$$

$$\left(\frac{V_1}{V}\right)^{.41} = \frac{T}{T_1}. \qquad \textbf{(87.)}\ \text{Art. } \textbf{1170.}$$

To obtain the area of the diagram representing the adiabatic compression of air, the following formula may be used which gives it directly when p and p_1 are the greater and lesser pressures, respectively, and V and V_1 their corresponding volumes:

$$\frac{pV - p_1V_1}{.41} = \text{area}. \qquad \textbf{(88.)}\ \text{Art. } \textbf{1172.}$$

EFFICIENCY OF A PERFECT HEAT ENGINE.

Let $c = \frac{P_1V_1}{T_1}$, and $r = \frac{V_2}{V_1}$, then, the efficiency of a perfect heat engine $= \frac{2.3026\,c\log r_1\,(T_1 - T_2)}{2.3026\,c\,T_1\log r_1} = E = \frac{T_1 - T_2}{T_1}$. **(89.)** Art. **1182.**

That is, *for a perfect heat engine, operating through a reversible cycle process, the efficiency of the machine is the ratio of the difference of the absolute temperatures of the sources of heat and of cold to the absolute temperature of the source of heat.*

FORMULAS USED IN STEAM AND STEAM ENGINES.

RELATION BETWEEN THE PRESSURE AND TEMPERATURE OF SATURATED STEAM.

Let t = temperature, Fahrenheit;

T = absolute temperature = $t + 460°$;

p = absolute pressure (pressure above vacuum) in pounds per sq. in.

$$\text{Log}\, p = 6.1007 - \frac{2{,}719.78}{T} - \frac{400{,}215}{T^2}. \quad \left\{ \begin{array}{l} \textbf{(90.)} \\ \text{Art. } \textbf{1197.} \end{array} \right.$$

TOTAL HEAT OF VAPORIZATION.

Let H = total heat of vaporization;

t = temperature;

$H = 1{,}081.94 + .305\, t.$ **(91.)** Art. **1200.**

SPECIFIC VOLUME OF SATURATED STEAM.

$p\, V^{\frac{17}{16}} = 475,$ **(92.)** Art. **1203.**

in which p is the pressure in pounds per square inch, and V the volume in cubic feet of a pound of steam at the given pressure.

WORK DONE IN THE CYLINDER OF A STEAM ENGINE.

Let P = the pressure on the piston in pounds per sq. ft.;

p = pressure on piston in pounds per sq. in.;

V = volume swept through by the piston;

W = work in foot-pounds.

Then, $W = P\, V = 144\, p\, V.$ **(93.)** Art. **1212.**

RELATION BETWEEN CLEARANCE, CUT-OFF, AND NUMBER OF EXPANSIONS, OR RATIO OF EXPANSION.

Let c = the number of expansions;

i = the clearance, expressed as a per cent. of the stroke;

k = the real cut-off;
k_1 = the apparent cut-off;
r = the apparent number of expansions $= \frac{1}{k_1}$.

Then, $e = \frac{1}{k}$ and $k = \frac{1}{e}$. **(96.)** Art. **1254.**

$$k = \frac{k_1 + i}{1 + i}. \quad \textbf{(97.)} \text{ Art. } \textbf{1254.}$$

TO FIND THE AREA OF A THEORETICAL DIAGRAM AND THE WORK REPRESENTED BY THE DIAGRAM.

Let A = total area of diagram in square inches;
p_1 = initial pressure measured in inches;
V_1 = volume at cut-off measured in inches;
L = work in foot-pounds;
a = net area of diagram;
h = scale used to lay off pressures;
h_1 = scale used to lay off volumes.

$$A = 2.3026\, p_1 V_1 \log \frac{V_2}{V_1}. \quad \textbf{(94.)} \text{ Art. } \textbf{1215.}$$

$$L = 144\, a\, h\, h_1. \quad \textbf{(95.)} \text{ Art. } \textbf{1215.}$$

INDICATED HORSEPOWER AND MEAN EFFECTIVE PRESSURE.

Let P = the M. E. P. in lb. per sq. in.;
A = the area of piston in sq. in.;
L = the length of stroke in ft.;
N = the No. of strokes per min.

Then, the work done per minute is $P\,L\,A\,N$ foot-pounds.
One horsepower = 33,000 foot-pounds per min.
Therefore, the indicated horsepower of the engine is found from the formula

$$\text{I. H. P.} = \frac{P\,L\,A\,N}{33{,}000}. \quad \textbf{(98.)} \text{ Art. } \textbf{1268.}$$

When the point of real cut-off, and the steam pressure

If the expansion curve is known, the M. E. P. may be found accurately by the following formula:

$$M.E.P. = \frac{p_1 v_1 (1 + \log_e r)}{v_2} - p_2 \qquad \textbf{98.}$$

Art. **1269.**

In which p_1 = absolute initial pressure = gauge pressure + 14.7 pounds;

v_1 = volume of cylinder;

v_2 = volume of piston displacement;

r = absolute back pressure.

p_2 is usually taken as 20 pounds for condensing engines, and 17 pounds for non-condensing engines.

RELATION BETWEEN LENGTH OF STROKE, NUMBER OF REVOLUTIONS, AND PISTON SPEED.

Let L = length of stroke in inches;

N = number of revolutions per minute;

S = piston speed in feet per minute.

$$S = \frac{2LN}{12}.$$

$$L = \frac{6S}{N}. \qquad \textbf{100.} \quad \text{Art. } \textbf{1270.}$$

$$N = \frac{6S}{L}.$$

RATIO OF EXPANSION IN A COMPOUND OR TRIPLE-EXPANSION ENGINE.

Let e = ratio of expansion in high-pressure cylinder;

E = total ratio of expansion;

v = volume of cylinder receiving steam from the boiler;

V = volume of cylinder exhausting into atmosphere or condenser.

Then, $$E = \frac{eV}{v}. \qquad \textbf{(102.)} \quad \text{Art. } \textbf{1298.}$$

RATIO BETWEEN THE CYLINDERS OF A COMPOUND ENGINE.

Letting the letters have the same meaning as in the last formula, then either of the following formulas may be used:

$$E = 2.72\,\frac{V}{v}, \text{ or } \frac{V}{v} = \frac{E}{2.72}. \qquad \textbf{(103.)} \text{ Art. } \textbf{1306.}$$

$$\frac{V}{v} = \sqrt{E}. \qquad \textbf{(104.)} \text{ Art. } \textbf{1306.}$$

AMOUNT OF WATER AND THE COOLING SURFACE FOR CONDENSERS.

Water Required by a Condenser.

Let t_1 = the temperature of departing condensing water;
t_2 = the temperature of entering condensing water;
t_3 = the temperature of the condensed steam upon leaving the condenser;
H = total heat of one pound of steam at the pressure of the exhaust;
W = the weight of water required per pound of steam condensed.

$$W = \frac{H - t_3 + 32}{t_1 - t_2}. \qquad \textbf{(105.)} \text{ Art. } \textbf{1323.}$$

Cooling Surface.

Let S = the required surface in square feet;
W = total weight of steam used per hour.

Then, $S = .0944\ W.$ **(106.)** Art. **1325.**

TO FIND THE WEIGHT OF A FLY-WHEEL.

Let V_1 = the greatest velocity of the crank-pin in ft. per sec.;
V_2 = the least velocity of the crank-pin in ft. per sec.;
V_0 = average velocity of crank-pin in ft. per sec.;
W = required weight of fly-wheel in pounds;
H = the number of foot-pounds per sq. in. of piston represented by the excess of crank effect over the resistance;
A = area of piston in square inches;
n = ratio between radius of fly-wheel and length of crank;

$E = \dfrac{V_1 - V_2}{V_0}$ = coefficient of unsteadiness.

$$W = \frac{A\,H\,g}{n^2\,E\,V_0^2}. \qquad \textbf{(107.)} \text{ Art. } \textbf{1328.}$$

FORMULAS USED IN PRINCIPLES OF REFRIGERATION.

TRANSFER OF HEAT.

Let Q_1 = heat delivered to condenser in B. T. U.;
Q_2 = heat taken from body cooled in B. T. U.;
W = work in foot-pounds done by engine on working fluid;
J = 778 = mechanical equivalent of heat.

Then, $$Q_1 = Q_2 + \frac{W}{J}. \qquad \textbf{(108.)}$$ Art. **1337.**

REFRIGERATING CAPACITY.

Let H = B. T. U. abstracted from cold body in 24 hours;
h = B. T. U. abstracted from cold body in 1 hour;
F = refrigerating capacity, expressed in tons.

Then, $$F = \frac{H}{285{,}300}, \qquad \textbf{(109.)}$$ Art. **1338.**

or $$F = \frac{h}{11{,}887.5}. \qquad \textbf{(110.)}$$ Art. **1338.**

THEORETICAL MAXIMUM EFFICIENCY OF A HEAT ENGINE.

Let E = theoretical maximum efficiency;
Q_1 = heat given up by the hot body in B. T. U.;
Q_2 = heat rejected to the cold body in B. T. U.;
T_1 = absolute temperature at which heat is delivered to condenser;
T_2 = absolute temperature at which heat is abstracted from cold body.

Then, $$E = \frac{Q_2}{Q_1 - Q_2}. \qquad \textbf{(111.)}$$ Art. **1340.**

$$E = \frac{T_2}{T_1 - T_2}. \qquad \textbf{(112.)}$$ Art. **1340.**

$$E = \frac{J Q_2}{W}. \qquad \textbf{(113.)}$$ Art. **1340.**

In the last formula, J and W have the same significance as in formula **108.**

GENERAL THEORY OF AIR MACHINE.

In the following discussion, it will be assumed, for the sake of simplicity, that compression and expansion are adiabatic and that the air is drawn into the compressor from the cooling chamber, so that the machine works through a closed cycle. The clearance of the two cylinders will be neglected. Referring to the diagram, Fig. 1, let V_a, V_b, V_c, V_d denote the volumes, T_a, T_b, T_c, T_d the absolute temperatures, and t_a, t_b, t_c, t_d the ordinary temperatures of the air when in the states represented by the points A, B, C, and D, respectively; and let p_1 and p_2 denote the pressures of the air during the operations $D\,A$ and $B\,C$, respectively; also let s_p and s_v denote, respectively, the specific heat of air at constant pressure and constant volume, and let M denote the weight of air used per stroke of the compressor.

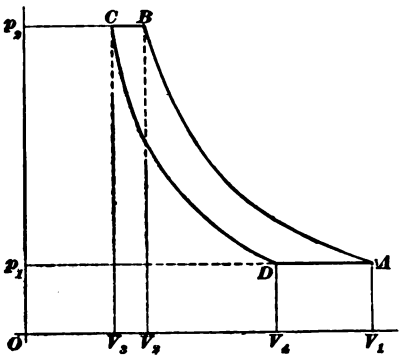

FIG. 1.

The temperatures t_a of the cooling chamber and t_c of the air as it leaves the condenser are known or assumed, and the temperatures t_b and t_d can be obtained by formula **86**, *Heat*. Thus,

$$\frac{T_b}{T_a} = \left(\frac{p_2}{p_1}\right)^{.29078} \text{ and } \frac{T_d}{T_c} = \left(\frac{p_1}{p_2}\right)^{.29078} = \frac{T_a}{T_b}. \quad (a)$$

To find the volume of the air at the end of compression, we have, from formula **81**,

$$p_1 V_a^{1.41} = p_2 V_b^{1.41},$$

or

$$V_b = V_a \left(\frac{p_1}{p_2}\right)^{\frac{1}{1.41}}. \quad (b)$$

The volume of the air during the cooling in the condenser

decreases from V_b to V_c at constant pressure. According to formula **71**,

$$p_2 V_b = R M T_b,$$

and

$$p_2 V_c = R M T_c.$$

Dividing,

$$\frac{V_b}{V_c} = \frac{T_b}{T_c},$$

or

$$V_c = V_b \frac{T_c}{T_b}. \quad (c)$$

Finally,

$$p_2 V_c^{1.41} = p_1 V_d^{1.41},$$

or

$$V_d = V_c \left(\frac{p_2}{p_1}\right)^{\frac{1}{1.41}}.$$

Since from (b)

$$\left(\frac{p_1}{p_2}\right)^{\frac{1}{1.41}} = \frac{V_b}{V_a},$$

we have

$$V_d = V_c \frac{V_a}{V_b}, \quad \text{or} \quad \frac{V_d}{V_c} = \frac{V_a}{V_b}. \quad (d)$$

The preceding formulas enable us from the assumed data to calculate the volume and temperature of the gas at each of the four points A, B, C, and D.

The heat given up by the air to the condenser is

$$Q_1 = s_p M (t_b - t_c). \quad (e)$$ (See Art. **1135**, *Heat.*)

The heat absorbed by the air from the cooler as it expands from D to A is

$$Q_2 = s_p M (t_a - t_d). \quad (f)$$

The specific heat s_p is used for the reason that the air passes through the condenser and through the cooler at constant pressure, as shown by the lines $B\,C$ and $D\,A$.

The heat equivalent of the work done on the air—represented by the area $A\,B\,C\,D$—must be precisely the difference between the heat delivered to the condenser and that abstracted from the cooler. Hence, denoting the net work by W, we have

$$\frac{W}{J} = Q_1 - Q_2 = s_p M [(t_b - t_c) - (t_a - t_d)],$$

or

$$W = J s_p M [(t_b - t_c) - (t_a - t_d)]$$
$$= J s_p M [(T_b - T_c) - (T_a - T_d)]. \quad (g)$$

The theoretical efficiency is therefore

$$E = \frac{J Q_2}{W} = \frac{J s_p M (T_a - T_d)}{J s_p M [(T_b - T_c) - (T_a - T_d)]}$$

$$= \frac{T_a - T_d}{(T_b - T_c) - (T_a - T_d)}. \quad (h)$$

Since $\frac{T_d}{T_c} = \frac{T_a}{T_b}$, it can readily be shown that the expression reduces to

$$E = \frac{T_a}{T_b - T_a} = \frac{T_d}{T_c - T_d}. \quad (i)$$

Since the net work per stroke is W, if we denote the number of strokes per minute by n, the horsepower required to drive the machine is

$$H = \frac{n W}{33{,}000}. \quad (j)$$

The gross horsepower required will of course be much greater, on account of the friction of the two pistons and of the other parts of the machine.

If desired, the work W may be expressed in terms of the pressures and volumes instead of temperatures. Thus, using formula **88**, *Heat*,

$$W_{ab} \text{ (area } A\,B\,V_b\,V_a) = \frac{144\,(p_2 V_b - p_1 V_a)}{.41}.$$

$$W_{bc} \text{ (area } B\,C\,V_c\,V_b) = 144\,p_2 (V_b - V_c).$$

$$W_{cd} \text{ (area } C\,D\,V_d\,V_c) = \frac{144\,(p_2 V_c - p_1 V_d)}{.41}.$$

$$W_{da} \text{ (area } D\,A\,V_a\,V_d) = 144\,p_1 (V_a - V_d).$$

$$W = W_{ab} + W_{bc} - W_{cd} - W_{da} =$$

$$144 \times \frac{1.41}{.41} [p_2 (V_b - V_c) - p_1 (V_a - V_d)]. \quad (k)$$

The factor 144 is used to reduce the pressures from pounds per square inch to pounds per square foot.

The heat Q_1 is given up by the air in the condenser. If G denotes the weight of cooling water used per stroke, and

FORMULAS FOR CALCULATING PROPERTIES OF AMMONIA THAT ARE DEPENDENT UPON PRESSURE AND TEMPERATURE.

The leading properties of ammonia that are dependent upon the pressure or temperature are given in Table 26, which is taken from Wood's "Thermodynamics." The table is calculated from the following formulas, which are based partly on experimental data and partly on thermodynamic principles:

Let p = absolute pressure of gas or vapor in pounds per square inch;
t = temperature of vapor, Fahrenheit;
v = volume of one pound of vapor;
v_1 = volume of one pound of ammonia liquid;
w = weight of one cubic foot of vapor;
r = latent heat of vaporization in B. T. U.

Then, $\log p = 6.2495 - \frac{2{,}196}{460.66 + t}$. **(115.)** Art. **1358.**

$$v_1 = \frac{.016}{.6502 - .000778\,t}. \qquad \textbf{(116.)} \text{ Art. } \textbf{1358.}$$

$$v = v_1 + .00107\,\frac{r}{p}\,t + .4923\,\frac{r}{p}. \qquad \textbf{(117.)} \text{ Art. } \textbf{1358.}$$

$$w = \frac{1}{v}.$$

$$r = 555.5 - .613\,t - .000219\,t^2. \qquad \textbf{(118.)} \text{ Art. } \textbf{1358.}$$

$$p\,v = .62\,M\,T, \qquad \textbf{(119.)} \text{ Art. } \textbf{1360.}$$

where M is the weight of gas and T is the absolute temperature.

Corresponding to formulas **81, 86,** and **87,** *Heat,* we have the following approximate formulas for the *adiabatic* expansion of superheated ammonia:

$$p_1 V_1^{1.3} = p_2 V_2^{1.3}. \qquad \textbf{(120.)} \text{ Art. } \textbf{1360.}$$

$$\frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{.3}{1.3}} = \left(\frac{p_1}{p_2}\right)^{.2308}. \qquad \textbf{(121.)} \text{ Art. } \textbf{1360.}$$

$$\frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{.3}. \qquad \textbf{(122.)} \text{ Art. } \textbf{1360.}$$

GENERAL THEORY OF AMMONIA COMPRESSION MACHINES.

Heat Transfers.—Let T_a denote the absolute temperature of the gas in the state A, Fig. 2, which is practically

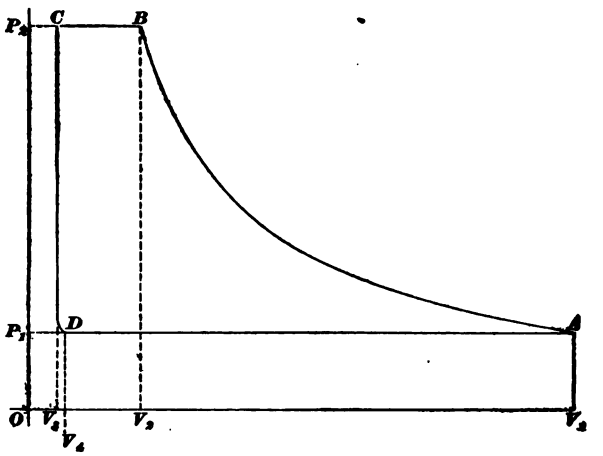

FIG. 2.

the temperature of the coil B, Fig. 3, and let T_b denote the temperature of the gas at the end of compression. Since

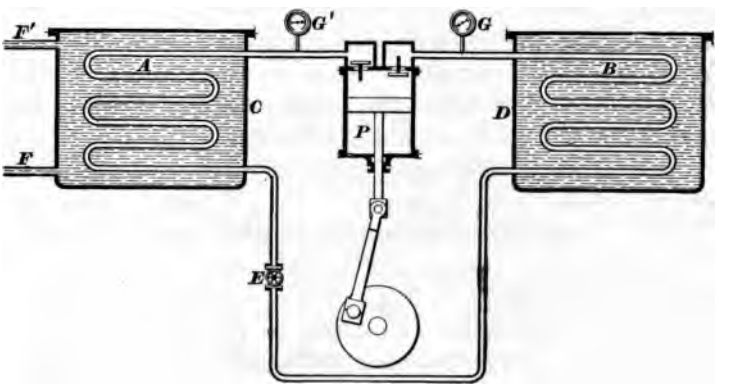

FIG. 3.

the gas is superheated during the compression, the final temperature T_b is given by formula **121:**

$$\frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{n-1}{n}}.$$

or

$$T_1 = T_2\left(\frac{p_1}{p_2}\right)^{\frac{n-1}{n}}.$$

Let T_1 denote the final temperature that the gas or vapor attains in the condenser, that is, T_1 is the temperature of condensation. Let r_2 denote the latent heat of vaporization at the temperature T_2. The specific heat of ammonia gas being 0.5, the heat given up by a pound of the gas in cooling from T_2 to T_1 is $0.5(T_2 - T_1)$ B. T. U. In condensing, a pound of the gas gives up further r_2 B. T. U. If M denotes the weight in pounds of gas used per stroke, then the heat given up to the condenser per stroke is evidently

$$\left.\begin{aligned} Q_2 &= M[0.5(T_2 - T_1) + r_2] \text{ B. T. U.} \\ &= M[0.5(t_2 - t_1) + r_2] \text{ B. T. U.} \end{aligned}\right\} \quad (a)$$

If t_c and t_1 denote, respectively, the temperature of the cooling water as it enters and as it leaves the condenser, then the weight of cooling water required per stroke is

$$G = \frac{M[0.5(t_2 - t_1) + r_2]}{t_1 - t_c}. \quad (b)$$

For the sake of simplicity, we will assume that the pressure of the liquid ammonia drops from P_2 to P_1 before vaporization begins; while this is not precisely the case, the difference in the results is not appreciable. During the fall of temperature from T_c to T_a, the original temperature of the gas in the coil B, a pound of the liquid gives up $s(T_c - T_a)$ heat-units, where s denotes the specific heat of liquid ammonia. During the vaporization in the coil B, each pound absorbs r_1 B. T. U., where r_1 denotes the latent heat of vaporization corresponding to the pressure P_1 and temperature T_a. The net heat abstracted from the refrigerator per stroke is therefore

$$\left.\begin{aligned} Q_1 &= M[r_1 - s(T_c - T_a)] \text{ B. T. U.} \\ &= M[r_1 - s(t_c - t_a)] \text{ B. T. U.} \end{aligned}\right\} \quad (c)$$

Since the specific heat of liquid ammonia is practically 1, we may write the equation

$$\left.\begin{aligned} Q_2 &= M[r_1 - (T_c - T_a)] \text{ B. T. U.} \\ &= M[r_1 - (t_c - t_a)] \text{ B. T. U.} \end{aligned}\right\} \quad (d)$$

The work of the compressor per stroke in foot-pounds is

$$W = J(Q_1 - Q_2) = J\,M\,[r_2 - r_1 + .508\,(t_b - t_c) + t_c - t_a].$$

If n denotes the number of strokes per minute, the theoretical horsepower of the compressor is

$$H = \frac{nJM[r_2 - r_1 + .508\,(t_b - t_c) + t_c - t_a]}{33{,}000}. \quad (e)$$

Art. **1370.**

Efficiency.—The theoretical efficiency of the refrigerating-machine is

$$E = \frac{JQ_2}{W} = \frac{r_1 - (T_c - T_a)}{r_2 - r_1 + .508\,(T_b - T_c) + T_c - T_a}. \quad (f)$$

If we denote by T_i the temperature of the cold room or of the brine, if the latter be used, then the effective range of temperature is $T_f - T_i$, where T_f, as before, denotes the absolute temperature of the cooling water as it leaves the condenser. In practice T_i is always a little higher (5° to 10°) than the temperature T_a of the ammonia in the refrigerating coils, and the temperature T_c of the ammonia in the condenser coils is always higher than T_f. The theoretical maximum efficiency for this temperature range is

$$E_m = \frac{T_i}{T_f - T_i}. \quad (g)$$

(See Art. **1346.**) Art. **1371.**

The economy of a machine may be judged by comparing the actual efficiency with this ideal efficiency E_m.

Volume of Compressor Cylinder.—Let v denote the volume of a pound of ammonia vapor at the pressure p_1 in the coil B; then, since M pounds of vapor are used per stroke, the cubic capacity of the cylinder must be

$$C = Mv \text{ cubic feet.} \quad (h)$$

Art. **1372.**

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] **123. to 133.**

QUANTITY OF BRINE REQUIRED TO REFRIGERATE A GIVEN SECTION.

$$Q = \frac{w\,T}{t_2 - t_1} \qquad \textbf{124. to 144.}$$

in which Q = gallons of brine required per minute;
T = tonnage of section to be cooled;
t_1 = temperature of brine inlet;
t_2 = temperature of brine outlet.

SIZE OF PIPE.

The determination of the size of the pipe necessary to carry a given quantity of brine is based on D'Arcy's formula for the flow of water through clean cast-iron pipes. This formula is practically correct for wrought-iron pipes. In case there are very many elbows in the work, it is best to [illegible] from the results given by the formula.

[illegible] Q gallons of brine delivered per minute;
h head in feet required to overcome friction;
l length of pipe in feet.

Then, for 1-inch pipe,

$$Q = 28.5\sqrt{\frac{h}{l}}. \qquad \textbf{(125.)} \quad \text{Art. } \textbf{1445.}$$

The formula as given applies only to 1-inch pipe. If it is desired to ascertain the quantity of brine that will flow through pipes of other diameters, it is necessary to multiply the amount that a 1-inch pipe will deliver by the factor in the following conversion table opposite the given diameter:

Diameter.	Factor.
1 inch	1.00
1¼ inches	1.84
1½ "	3.02
2 "	6.53
2½ "	10.23
3 "	19.10
4 "	40.50
5 "	72.00
6 "	115.00

If we denote by G the actual quantity of brine used per minute and by Q the quantity delivered per minute by a 1-inch pipe, then the factor required will be given by the quotient $\frac{G}{Q}$. The size of pipe required can then be determined from the value found for the factor.

CAPACITY OF DIRECT-EXPANSION SYSTEM.

As stated in Art. **1452,** an accurate determination of the quantity of refrigeration produced by a direct-expansion system is not possible, and it is necessary to resort to calculation to obtain an approximate result. From formula **123,** the refrigeration in 24 hours, expressed in tons of ice, is $F = .00505\, n\, M\, [r_1 - (t_c - t_a)]$, and the weight M of ammonia circulated per stroke is $M = \frac{C}{v} = C\, w$, where C denotes the volume of the compressor cylinder in cubic feet, v the volume of a pound of ammonia vapor at the

pressure in expansion coil, and w the weight of a cubic foot of the vapor at the same pressure. Substituting, we have

$$F = .00505\, n\, C\, w\, [r_1 - (t_o - t_a)]. \qquad \textbf{(126.)}$$ Art. **1454.**

The factor n is the number of compression strokes per minute; in single-acting compressors n will be equal to the number of revolutions per minute, and in double-acting machines to double that number. This formula gives the theoretical tonnage of the machine. To allow for such losses as clearance and cylinder superheating, deduct 25 per cent. from the result in case of a single-acting machine and 30 per cent. for a double-acting machine.

To obtain a rough approximation to the capacity, the following rule of thumb is sometimes used: With a suction pressure of 15 pounds, gauge, and a head pressure of 150 pounds, a well-made single-acting compressor with small clearance spaces gives an ice-melting effect of 1 ton for 4½ cubic feet of piston displacement per minute. With double-acting compressors, allow 5 to 6 cubic feet per minute for each ton.

DIRECT MEASUREMENT OF AMMONIA.

The formula for capacity applies to compressors working under the most favorable conditions, with small clearance losses and no leak about valves or pistons. The cylinder superheating is based upon a suction pressure of 15 pounds and a back pressure of 150 pounds. This loss is found in case of wet or dry compression or oil injection, the exact percentage differing with make of machine. To make even an approximately exact test upon a compression machine running with a direct-expansion system, it is necessary to measure directly the quantity of ammonia circulated by means of an ammonia meter in the feed line, between the receiver of the condenser and the expansion-valve.

The meter should be calibrated in cubic feet by means of water before being placed in the feed line, care being taken to thoroughly eliminate any remaining water before the

meter is connected up. The weight in pounds per cubic foot of the liquid anhydrous ammonia for any required head pressure is given in the table of Properties of Saturated Ammonia.

Let P denote the weight in pounds of anhydrous ammonia passed through the meter in 1 hour. Then the heat absorbed by the ammonia per hour is $P[r-(t_c-t_a)]$ B. T. U. and the capacity in tons per 24 hours is

$$F=\frac{24}{285,300}P[r-(t_c-t_a)]=.000084\,P[r-(t_c-t_a)]. \quad \textbf{(127.)}$$ Art. **1455.**

HEAT BALANCE IN ABSORPTION MACHINE.

The various quantities of heat with which we are concerned in the test of an absorption machine are the following: (1) The heat given up to the condensing water by the condenser, absorber, rectifier, and weak-liquor cooler; let this heat be denoted by Q_c. (2) The heat absorbed in the generator, Q_g. (3) The heat abstracted from the brine, Q_b. (4) The heat equivalent of the work of the pump, which may be denoted by Q_p.

To determine the quantity Q_c, it is necessary to measure the weight of condensing water flowing per minute or per hour and the temperature range. (Items 17 and 18, Schedule of Test.) The heat Q_g may be determined as follows:

Let S = weight of steam passing through the condenser per minute;
L = latent heat of steam at given pressure;
t_1 = temperature of steam at given pressure;
t_2 = temperature of water leaving generator.

In changing to water, each pound of steam gives up L B. T. U. and the water gives up in addition t_1-t_2 B. T. U. in passing from the temperature t_1 to t_2 (assuming, as is customary, that the specific heat of water is 1).

Therefore,

$$Q_g=S(L+t_1-t_2). \quad \textbf{(128.)}$$ Art. **1475.**

The heat Q_b is determined as in the test of the compression machine, and the heat Q_p is found from the pump indicator-diagrams.

The total heat given to the machine is evidently

$$Q_g + Q_b + Q_p,$$

and Q_c is the heat delivered by the machine to the condensing water; hence we have

$$Q_c = Q_g + Q_b + Q_p.$$

In practice, Q_p is so small that it may be neglected in forming the heat balance, and the equation becomes

$$Q_c = Q_g + Q_b.$$

FORMULAS USED IN REFRIGERATING AND ICE-MAKING MACHINERY.

SPECIFIC GRAVITY OF WORT AT ANY TEMPERATURE OTHER THAN 60°.

$$s = s_{60} + .00015\ (60 - t), \qquad \textbf{(129.)}\ \text{Art. } \textbf{1524.}$$

in which s is the specific gravity, t the temperature, and s_{60} the specific gravity at 60°, as given in Table 31. If t is greater than 60, the factor $60 - t$ is negative, which means that $t - 60$ should be multiplied by .00015, and the result subtracted from s_{60}.

REFRIGERATION REQUIRED FOR COOLING WORT.

The capacity of a brewery is usually expressed by the number of 31.5-gallon barrels brewed per day of 24 hours. Let this number be denoted by b. Also, let g be the specific gravity of the wort, s its specific heat, T its temperature after leaving the upper coil of the cooler, t the temperature to which it must be reduced in trickling over the lower coil, and H the number of B. T. U. required to effect this reduction of temperature. The value of T may be taken equal to the temperature of the water in the upper coil. The

weight of 31.5 gallons of water being 262.4 pounds, that of 1 barrel of wort is $262.4\,g$. Therefore,

$$H = 262.4\,g\,b\,s\,(T-t). \qquad \textbf{(130.)} \text{ Art. } \textbf{1527.}$$

If F is the number of tons of refrigeration corresponding to this heat, we have (formula **109**)

$$F = \frac{H}{285{,}300} = \frac{262.4\,g\,b\,s\,(T-t)}{285{,}300} = .0009197\,g\,b\,s\,(T-t).$$
$$\textbf{(131.)} \text{ Art. } \textbf{1527.}$$

The values of g and s are taken from tables, assuming a mean temperature $= \frac{1}{2}(T+t)$. Taking $T = 70°$, $t = 40°$, $g = 1.05$, and $s = .91$, the preceding formula becomes

$$F = .0009197 \times 1.05 \times .91 \times 30\,b = .02636\,b = \tfrac{1}{38}\,b, \text{ nearly.}$$
$$\textbf{(132.)} \text{ Art. } \textbf{1527.}$$

If in this formula we make $F = 1$, we get $b = 38$; that is, 1 ton of refrigerating effect will cool 38 barrels of wort from 70° to 40°.

REFRIGERATION REQUIRED TO REMOVE THE HEAT OF FERMENTATION.

The number H of B. T. U. necessary to dispose of the heat of fermentation of n barrels of wort is determined by the following formula:

$$H = 3\,n\,(s-s')\,(259+s). \qquad \textbf{(133.)} \text{ Art. } \textbf{1529.}$$

In this formula, s is the strength of the unfermented wort and s' the strength of the fermented wort (the beer), both as given by a Balling saccharometer. The corresponding number F of tons of refrigeration is

$$F = \frac{3\,n\,(s-s')\,(259+s)}{285{,}300} = .00001052\,n\,(s-s')\,(259+s).$$
$$\textbf{(134.)} \text{ Art. } \textbf{1529.}$$

A rough approximation, which is sufficiently close for many purposes, as for general estimates, is obtained by taking $s = 14$ and $s' = 4$, in which case the value of F becomes

$$F = .028\,n = \frac{n}{36}, \text{ nearly.} \qquad \textbf{(135.)} \text{ Art. } \textbf{1529.}$$

If in this formula we make $F = 1$, we get $n = 36$, which shows that to remove the heat of fermentation 1 ton of refrigerating capacity is required for every 36 barrels of beer. This applies to strong beers. For weak beers, 1 ton of refrigerating capacity may suffice for 50 or 60 barrels. For rough and preliminary estimates, 25 barrels are usually allowed per ton of refrigerating capacity.

REFRIGERATION REQUIRED TO KEEP THE TEMPERATURE OF THE ROOM.

The refrigeration required to keep the room at a constant temperature is computed by means of the following general formula:

$$H = c\,A\,(t - t_1), \qquad \textbf{(136.)}$$ Art. **1543.**

in which H = B. T. U. of refrigeration required to maintain a given space at a certain temperature t_1, when this space is separated from another, in which the temperature is t, by a surface whose area in square feet is A; and c = constant depending upon the material and thickness of the substance separating the two spaces. The value of the constant generally varies between 2 and 5. For rough estimates, it may be taken as equal to 3.

The preceding refrigeration may be reduced to tons by dividing by 285,300; that is, the amount F of refrigeration, expressed in tons, is

$$F = \frac{c\,A\,(t - t_1)}{285{,}300} = .000003505\,c\,A\,(t - t_1). \qquad \textbf{(137.)}$$ Art. **1543.**

Table 33 contains values of c as given in Siebel's *Mechanical Refrigeration.*

For double floors and ceilings, air-tight and well filled, so as to prevent the ingress of air, c may be taken as 2. When a room is separated from the outside by a hermetically closed air-space between two walls, the value of c for the outside wall may be used in the formula, but instead of the temperature t_1, a mean should be taken between t_1 and t, which is equivalent to using $\frac{1}{2}\,(t - t_1)$ instead of $t - t_1$.

For a wall consisting of several materials, the coefficient c may be found from the formula

$$c = \frac{1}{\frac{b_1}{c_1} + \frac{b_2}{c_2} + \frac{b_3}{c_3} + \ldots}, \qquad \textbf{(138.)} \text{ Art. } \textbf{1543.}$$

in which b_1, b_2, b_3, etc., are the thicknesses, and c_1, c_2, c_3, etc., the corresponding values of c for the several materials composing the wall.

In large cold-storage warehouses of 250,000 cubic feet or over, 1 ton of refrigeration will maintain 10,000 cubic feet of well-insulated space at a temperature of 30°, and 5,000 cubic feet at 15°. In small warehouses of 50,000 to 100,000 cubic feet capacity, 1 ton of refrigerating effect will maintain 6,000 cubic feet at cold-storage temperatures, and 3,000 at freezing temperatures. These figures do not include the refrigeration required to cool the goods.

REFRIGERATION REQUIRED TO COOL THE ARTICLES.

The amount of refrigeration required to reduce the goods from their temperature t to the temperature t_1 of the room is given by the formulas

$$H = (w_1 s_1 + w_2 s_2 + w_3 s_3 + \ldots)(t - t_1), \qquad \textbf{(139.)}$$
Art. **1545.**

$$F = \frac{H}{385{,}300} =$$

$$.000003505\,(w_1 s_1 + w_2 s_2 + w_3 s_3 + \ldots)(t - t_1), \qquad \textbf{(140.)}$$
Art. **1545.**

in which w_1, w_2, etc., are the weights in pounds of the different kinds of produce to be cooled, s_1, s_2, etc., their corresponding specific heats, and H and F are refrigeration units in B. T. U. and tons of refrigeration, respectively.

TONS OF REFRIGERATION REQUIRED.

If the weights of carcasses of different kinds are represented by w_1, w_2, w_3, etc., and the number of carcasses of each class by n_1, n_2, n_3, etc., the weights to be cooled will

be $n_1 w_1$, $n_2 w_2$, $n_3 w_3$, etc. Substituting these values for w_1, w_2, etc., in formula **140**, and putting $t - t_1 = 95° - 35° = 60°$, we get, for the tons of refrigeration required,

$$F = .000003505\,(n_1 w_1 s_1 + n_2 w_2 s_2 + \ldots) \times 60$$
$$= .0002103\,(n_1 w_1 s_1 + n_2 w_2 s_2 + \ldots). \qquad (141.)$$

Art. **1557.**

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